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Japan:

Comprehensive Department of New Sunshine Plan-Reference Material

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Comprehensive Development of New Sunshine Plan—Reference Material

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[Text]

Industrial Technology Council, MITI

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Joint Planning Committee Membership List (Continued)

	Name	Affiliation
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	Tsutomu Yamaguchi	Executive Director, Research Institute of Innovative Technology of the Earth (RITE)
	Koichi Yamanashi	Managing Director, New Energy Foundation
	Hitoshi Yoshizawa	Executive Director, Energy Research and Engineering Institute

Reference

1. Scenario for the Development and Introduction of Key Technologies
   Solar energy utilization
   Photovoltaic power generation
   Fuel cell power generation
   Super heat pump/energy accumulation system
   Geothermal
   Distributed battery power storage technology
   Ceramic gas turbine engines
   Superconductor power applications technology
   Coal liquefaction
   Coal gasification
   Wind power generation
   Marine energy (Ocean thermal energy power generation)
   Biomass energy
   Magma power generation

2. Analysis of Achievements Contributing to the Simultaneous Resolution of Sustained Economic Growth and Energy/Environmental Problems via the Sunshine/Moonlight Plans

3. R&D Trends in Energy/Environmental Technology in the United States and Europe

4. Overview of the Global Regeneration Plan

(Reference 1) Scenario for the Development and Introduction of Key Technologies [by technology field]

1. Solar Energy Utilization

R&D Overview

Development of solar systems capable of being applied to the various processes in industrial and non-industrial fields that require high levels of heat control. The following technology development programs are currently underway—From FY1979 on—Total funds of roughly ¥8.7 billion

[1] Development of component technologies

Development of the high performance adiabatic technology required for high-performance solar systems (FY1990-93)

[2] Development of advanced heat processing systems

Development of high-efficiency solar energy refrigeration technology that makes use of the heat of reaction between hydrogen and hydrogen absorbing alloys to attain via solar energy low temperatures of -20°C and under, a feat that has proved difficult for conventional heat-driven systems (FY1984-93).

[3] Passive solar systems

Development of passive devices with new functions such as transparent heat insulators and modulated light materials required in passive solar systems that regulate the intake and emission of solar light and energy using adiabators and building construction (FY1991-93).

Major R&D Results

1. Solar energy systems for private consumers

Research on this technology was completed in FY 1981, and we are currently implementing programs such as low-interest loans and subsidies designed to foster the widespread use of these systems. As of the end of 1991, 350,000 solar energy systems for private consumer use had been installed in Japan as a result of these propagation efforts.

2. Solar energy systems for industrial use

Air heat collector-style drying (fixed heat processing type) systems and refrigerated warehouse (advanced heat processing type) systems have been developed and have succeeded in attaining a solar energy dependency ratio of 50% and long-term continuous operation.

Current State of Utilization

As of the end of FY 1990, there were 1) approximately 370,000 solar energy systems, and 2) roughly 4.6 million solar energy water heaters in use in Japan, furnishing the equivalent of roughly 1.4 million kiloliters of petroleum-generated energy. This worked out to a utilization ratio of roughly 12% (out of a total of 40 million households).

Current State of R&D in the Private Sector

Private industry is currently developing technology for commercializing solar energy equipment for private consumers. Industrial solar energy equipment is rapidly approaching full-scale practicalization, and all-out research projects are no longer being carried out. Research is being carried out now on passive solar systems as part of R&D efforts aimed at developing building materials for family housing.

Anticipated Supply Potential

[1] Since solar energy systems for private consumers have already been commercialized, their utilization should continue to increase steadily.

[2] The results of R&D on industrial solar energy systems will lead to practicalization.

[3] The latent utilization potential for solar energy systems for private and industrial use is about 17 million kiloliters [kl] (in terms of petroleum-generated energy).

—25.2 million private homes, or roughly 5.9 million kl

—1.1 million private offices and workplaces, or roughly 5.7 million kl

—1.1 million industrial facilities, or roughly 5.7 million kl (Based on data obtained from NEDO's New Energy Utilization Vision)

Potential 15 million kl

Remarks Calculated based on the assumption that 100% of the 25 million private homes, 100% of the 1.1 million private offices and workplaces and 60% of the 1.1 million industrial facilities will install solar energy systems.

Future Development/Utilization Plans

1. Technology development tasks

(1) Industrial solar systems

[1] Component technology: for realizing higher temperatures, lower-cost heat insulators and higher efficiency.

[2] New utilization technology systems (expanded temperature zones): Technology development is necessary for industrial solar systems requiring low temperature heat control.

(2) Passive solar systems

[1] Technology for increasing the surface area and service life of modulated light materials

[2] Technology for enhancing the strength of transparent heat insulators.

2. Near-term utilization plans. The following programs are currently being implemented to promote utilization:

(1) A low-interest rate loan system for household solar energy systems Loans for FY1992 reached ¥4.8 billion

(2) Solar system installation subsidy system for specified public facilities.

—Facilities targeted: educational and medical treatment facilities.

—Budget: FY 1992 budget was ¥400 million.

2. Photovoltaic Power Generation

R&D Overview

Development of technology for the manufacture of solar batteries and photovoltaic power generation systems aimed at lowering the costs involved in achieving the early practicalization of photovoltaic power generation.

—Development period: FY1979 on

—Total development costs: approximately ¥100 billion

1. Solar battery production technology

[1] Development of thin solar batteries and laminated (layered) solar batteries as a means of lowering costs while increasing efficiency of new-types of solar batteries (poly-crystalline solar batteries) (FY1988-92). Based on results achieved thus far, research and development work will commence in FY1993 on production technology for even less costly thin polycrystalline solar batteries.

[2] Amorphous solar batteries

Development of production technology geared towards increasing the quality, reliability and surface areas of amorphous solar batteries to heighten their performance capabilities (FY1983-92). Based on results achieved thus far, research and development work will commence in FY1993 on production technology for even higher performancethin amorphous solar batteries.

[3] Ultrahigh efficiency solar batteries

Development of next-generation solar batteries that are ultrahigh efficiency batteries (single crystal silicon solar batteries and/or compound semiconductor solar batteries) that are expected to double the conversion efficiency (30-40%) of current solar batteries (FY1990-?).

2. Photovoltaic power generation system

Development of low-cost, high-efficiency auxiliary equipment, such as invertors, storage batteries and racks as a means of lowering the costs and increasing the stability of photovoltaic power supply equipment, plus the development of various evaluation methods and research on system interconnection for the construction of optimum systems.

Major R&D Results

1. Succeeded in lowering the cost of manufacturing solar batteries to just slightly more than 1/30 what they were at the start of research on these devices in FY1979, i.e. from ¥20,000-30,000/W to ¥650/W (See below diagram [not reproduced]).

2. Succeeded in lowering the cost of producing power with photovoltaic power generating systems to just over one-tenth what they were originally, i.e. from roughly ¥2,000/kWh to about ¥120/kWh.

3. Achieved amorphous solar batteries with the highest conversion efficiency in the world (conversion efficiency of 11.1% with a 10 cm^2 battery) and increased their surface area by 9.7% to 30x40 cm.

Current State of Utilization

1. Solar battery output

Production output of solar batteries is steadily increasing, with Japan producing one-third of the world supply.

World 1986-26MW, 1991-55MW

Japan: 1986-13MW, 1991-20MW

2. Utilization of photovoltaic power generation systems

There were roughly 3,000 kW of power being generated in Japan as of the end of FY1991 by photovoltaic power generation systems, the majority of which were being used for R&D purposes.

3. Principal utilization examples (NEDO)

—200kW for testing system interconnectability (Rokko [phonetic] Island)

—750 kW for validation testing (Seiben-cho [phonetic], Okinawa)

Current State of R&D in the Private Sector

Power companies are currently carrying out operation-based research to validate their respective photovoltaic power generation systems.

[1] Tokyo Electric Power Corporation is conducting system interconnection validation testing on a 50kW system at Urawa.

[2] Kansai Electric Power Corporation is test operating a 50kW light-converging type photovoltaic power generation system.

Anticipated Supply Potential

[1] Utilization ratio will rise in line with lowering of photovoltaic power costs to private households and outlying islands and/or other remote areas where conventional power generation costs are still high.

[2] Over the long run, the photovoltaic power supply per user will improve in line with the enhancement of power generation efficiency.

[3] Latent utilization potential is calculated as 340 million kW (According to data compiled by the Photovoltaic Power Generation Technology Research Consortium).

—104 million kW for power plants

—71 million kW for private homes

—69 million kW for plants/factories

—35 million kW for outlying islands and other remote areas

—23 million kW for power sources for public facilities

—17 million kW for power sources for industrial facilities

—10 million kW for power sources for the forestry, agriculture and marine industries

—9 million kW other uses Total: 338 million kW

Note: Photovoltaic power generation systems have an operation rate of 12%, compared to the operation rate of 70% for conventional power plants. This means that actual system capacity is one-sixth that of conventional power plants. Example: 30 million kW of photovoltaic power generated for industrial use, for instance, would be equivalent to 5 million kW generated by a large-scale thermal power generation plant.

Potential

—70 million kW (18 million kl)

Remarks 25% of the 40 million households in Japan are expected to install personal photovoltaic power generation systems (4kW x 1,000 households), and roughly 30 million kW of photovoltaic power is expected to be generated for industrial use (See note above).

Future Development/Utilization Plans

1. Technology development tasks

In addition to promoting technological development aimed at achieving photovoltaic power generation costs of ¥20/kWh by the first part of the year 2000, plans also call for promoting the development of revolutionary solar batteries capable of large-scale power generation in and after the year 2000.

(1) Solar batteries

[1] Polycrystalline solar batteries

Development of technology aimed at lowering the cost of the continuous casting of silicon for use as solar battery substrates, of increasing substrate processing times and of simplifying processing methods. Employ modular structures capable of frameless (integral) construction and batch wiring to lower costs and achieve 15% modular efficiency.

[2] Amorphous solar batteries

Development of technology for employing film substrates and lowering costs, stabilizing quality and increasing production speed via high-speed laser patterning techniques. Development of light deterioration prevention technology and the achievement of 10% modular efficiency after initial deterioration.

(2) Systems development

[1] Enhance efficiency of the overall system

Research and develop evaluation technology for the system as a whole, and establish uniform evaluation methods for auxiliary equipment such as invertors, storage batteries and interconnection devices.

[2] Simplification of auxiliary equipment

Development and standardization of devices and subsystems that surpass conventional auxiliary equipment in shape, structure and functions, and the development of high-performance, low-capacity storage batteries capable of handling power demand peaks for use on outlying islands and in times of disaster.

[3] Expanded utilization formats

Analysis and grasp of characteristics of output fluctuations caused by fluctuating solar radiation when multiple photovoltaic power generation systems are installed over a wide area, certification of optimum installation formats and studies on policies for interconnecting with other energy systems.

[4] Lower cost systems

Lower costs by enhancing the efficiency of photovoltaic power generationsystems as a whole, simplifying auxiliary equipment, enhancing storage battery capabilities and optimizing each utilization format.

2. Near-term utilization plans

All the power companies are promoting plans to introduce photovoltaic power generation systems in the several kW-500 kW class (total expected utilization equivalent to 2400 kW).

—Field testing business for new energy power generation.

—Subsidize expenses required for on-site testing of photovoltaic power generation systems.

—Budget for FY1992: ¥845 million

—Subsidy ratio: 2/3

3. Other Preparation of system interconnection guidelines. Presentation of surplus power purchasing menus by the power companies.

3. Fuel Cell Power Generation

R&D Overview Development of technology that generates power directly from the electrochemical reaction of oxygen in the atmosphere with hydrogen obtained by reforming natural gas, methanol and coal gas fuels. Currently carrying out research and development by matching up the [Illegible] of the four systems for generating power directly from electrochemical reactions described below, which differ as to type of electrolyte (a substance which, when dissolved in a suitable liquid, dissociates into ions (hydrogen ions), thus rendering the liquid electrically conducting) employed.

—Development period: FY1981-97

—Total funding: Approximately ¥70 billion

1. Phosphoric acid fuel cells

Promoted development of a centralized fuel cell power generation system (1,000 kW class), as well as an on-site system (200 kW class for industrial and outlying island use) (FY1981-90).

2. Fused carbonate fuel cell

Currently engaged in research and development work aimed at developing a 1,000 kW class fused carbonate fuel cell pilot plant that will feature higher power generation efficiency (45-50%) than phosphoric acid type fuel cells and be capable of using coal gas and a variety of other fuels (FY1981-97).

3. Solid electrolyte fuel cells Currently developing a several kW class solid electrolyte (ceramics, etc) fuel cell that is expected to yield even higher power generation efficiency (50-60%) than fused carbonate fuel cells (FY1981-97).

Major R&D Results

1. Phosphoric acid fuel cells

[1] Achieved power generation efficiency of 39.7%, the highest in the world, under normal pressure operating conditions.

[2] Achieved a high integrated efficiency rate of 80.2% with a co- generation phosphoric acid fuel cell system.

[3] First in the world to succeed in recovering heat in the form of 170°C steam (Up until now, heat recovery had only been achieved in the form of hot water.). Based on these achievements, small-scale phosphoric acid fuel cells in the 200 kW class are now ready to be commercialized. (The Agency of Natural Resources and Energy is currently undertaking research and development aimed at practicalizing large-scale phosphoric acid fuel cells in the 1,000 kW and over class).

2. Fused carbonate fuel cells

Succeeded in achieving rated output operation in each of the 1 kW, 10 kW, 25 kW and 50 kW classes.

3. Solid electrolyte fuel cells Developed fuel cell production technology for the several hundred watt class of solid electrolyte fuel cells.

Current State of Utilization

As of FY 1991, fuel cells in Japan, primarily for R&D purposes, were turning out roughly 13,000 kW of power. Principal utilization examples.

(1) Examples of fuel cell use related to the Moonlight Plan.

[1] 1,000 kW class fuel cell used as an alternative to thermal power generation (FY1987-89).

[2] 1,000 kW class dispersed fuel cell (FY1988).

[3] 200 kW class fuel cell for operating use (FY1989-91).

[4] 200 kW class fuel cell for generating power on outlying islands (FY1989-91).

(2) Examples of non-Moonlight Plan-related fuel cells.

[1] 4,500 kW fuel cell operated by Tokyo Electric Power Corporation (FY1983-85).

[2] 11,000 kW fuel cell operated by Tokyo Electric Power Corporation (FY1990-92).

Current State of R&D in the Private Sector

Research efforts in the private sector are the closest to commercializing phosphoric acid fuel cells.

[1] Electric power industry—Tokyo Electric Power Corporation is researching the feasibility of operating an 11 MW phosphoric acid fuel cell plant (at its Satsui [sic] thermal power plant).

—10 electric power companies plan to introduce and operate 30 fuel cells in the 50-200 kW class.

—The Agency for Natural Resources and Energy is taking part in the development of a 5 MW fuel cell power plant for local power supply purposes as part of the "City Energy Center Fuel Cell Technology Development" program.

[2] Gas industry

—The Tokyo Gas Company, Osaka Gas Company and others have plans for commercializing 50 kW and 100 kW fuel cell power plants.

—The Agency for Natural Resources and Energy is taking part in the development of a 1 MW fuel cell power plant for on-site use as part of the "City Energy Center Fuel Cell Technology Development" program.

Anticipated Supply Potential

[1] For the time being, promote the accelerated introduction of phosphoric acid fuel cells.

[2] Commence introduction of fused carbonic fuel cells beginning around the year 2005.

[3] Commence introduction of solid electrolyte fuel cells beginning around the year 2015.

[4] Of a total capacity for thermal power plants in the year 2010 of 133.2 million kW, co-generation via fuel cells is expected to account for 24.3 million kW.

[5] If we calculate the percentage of energy conserved via the enhancement of fuel cell efficiency and the utilization of heat resulting from co-generation operations, we see that:

—Phosphoric acid fuel cells: efficiency enhanced from 38% to 40%, and heat usage of 40%.

—Fused carbonic fuel cells: efficiency enhanced from 38% to 50%, and heat usage of 10% on average.

—Solid electrolyte fuel cells: efficiency enhanced from 38% to 60%, and heat usage of 10% on average.

Potential 54 million kW (70.4 million kl)

Remarks

—Phosphoric acid fuel cells: 500 kW x 40,000 units, 50,000 kW x 80 units;

—Fused carbonic fuel cells: 300,000 kW x 70 units;

—Solid electrolyte fuel cells: 300,000 kW x 30 units.

Future Development/Utilization Plans

1. Technology development tasks

(1) Reduction of costs

—By making the fuel cells themselves capable of higher output and higher [Illegible]

—By increasing fuel cell surface area

—By increasing fuel cell lamination

—By developing higher performance catalysts

(2) Development of more compact, lower-cost technologies

—By combining reformers and fuel converters and making them more compact.

—By developing higher performance, longer lasting catalysts for use in fuel reformers.

(3) Develop large-scale fuel cells and validate their long-term operation. Carry out research aimed at validating operation from the standpoint of confirming reliability in line with commercialization.

2. Near-term utilization plans

(1) Electric power companies and gas companies are planning to utilize fuel cells to conduct research aimed at validating their operation.

—The utilization outlook for electric power companies is roughly 20,000 kW.

(2) Field testing business for new energy power generation.

—Subsidize expenses required for onsite testing of fuel cell systems.

—Total budget for FY1992: ¥635 million

—Subsidy ratio: 1/3.

4. Super Heat Pump/Energy Accumulation Systems

R&D Overview

Development of high-performance, compression-type heat pumps and chemical heat accumulators required to enhance energy utilization efficiency and level power demand load by recovering and storing with high efficiency and in a high density form low grade energy not used during night-time power generation operations and supplying this recovered energy to large-scale air conditioners and industrial processes during the afternoon hours.

—Development period: FY1984-92.

—Total funding: ¥10 billion

1. High-performance heat pumps

   Development of heat pumps with the following performance capabilities:

   [1] High efficiency—Heat pumps that possess the capabilities to double the coefficient of performance (heat output/required power) from the 3-4 achieved with conventional heat pumps to 6-8.

   [2] High temperature output—Heat pumps capable of outputting 150-300°C of heat as their maximum output temperatures at a coefficient of performance of around three (conventional heat pumps can only generate 110°C.

2. Chemical heat storage—By developing heat storage technology that uses chemical reactions to store heat, it will be possible to construct compact heat storage equipment that is roughly one-fifth the size of conventional water heat storage equipment.

Major R&D Results

Research and development work in this field is in its final stages, and results achieved thusfar are outlined below.

1. Achieved the sought after coefficient of performance of 6-8.

2. Alternative CFC heat pump

   —First in the world to apply this technology to an alternative CFC heat pump.

3. Affects on component technologies

   —Approximately 400 stainless plate fin heat exchangers developed as component technology for the super heat pumps are being utilized for waste heat recovery in fuel cells and gas engine co-generation systems. (Utilization examples)

   —Heat exchangers in operational phosphoric acid fuel cells (Hotel Plaza: Kansai Electric Company)

   —Heat exchangers in a gas engine co-generation system in operation in Kawasaki.

Current State of Utilization

1. Conventional heat pumps

   Conventional heat pumps come in a variety of sizes and are put to various applications, to include large-scale regional heating and cooling businesses and as refrigerators in plants and factories. (Examples of regional heating and cooling businesses)

   —Hakozaki (Tokyo Electric Power Corporation): utilizes heat from river water (from 1989).

   —The Tokyo subcenter of [Illegible] (Tokyo Electric Power Company): utilizes waste heat generated during sewerage processing (from 1990).

   —Hikarigaoka apartment complex (Tokyo Heat Supply Company [sic]): utilizes waste heat from underground power transmission facilities and garbage incineration operations (from 1983).

2. Super heat pumps

   As of this time, the only utilization of super heat pumps is in connection with research activities related to the Moonlight Plan, but studies are underway to introduce a super heat pump into the heating and cooling system for the Tokyo subcenter of Rinkai [sic].

Current State of R&D in the Private Sector

1. Private firms are engaged in research aimed primarily at developing conventional heat pumps for commercial purposes.

2. High-performance heat pumps Members of the private sector are currently making use of the Agency for Natural Resources and Energy's system of "Subsidies for Developing Technologies for the Utilization of Unused Energy" to develop high-performance heat pumps.

   —Budget for FY 1992: hundreds of million yen [Exact amount not given].

   —Subsidy ratio: 1/2.

Anticipated Supply Potential

[1] If we calculate the amount of conserved energy by usubtracting the amount of driving energy from the amount of supplied energy ((supplied energy) - (driving energy)), the amount of energy conservation achieved with super heat pumps works out to 50% of supplied energy based on a coefficient of performance of six (6) (If required power is equal to one (1) and supplied energy equals six (6), then the actual driving energy is 2.7 with an average power generation efficiency of 38%, i.e. (6-2.7)/6 x 100 = 50 (%)). (Note: coefficient of performance = heat output/required power).

[2] The latent utilization potential for heat pumps by volume of energy consumed is ultimately 20%, primarily in the fields of heating, hot water supply and the utilization of heat in industrial processes (Based on FY1985 figures, ultimate energy consumption volume = 2706 x 1012 kcal, and total latent supply potential by volume is 550 x 1012 kcal).

Potential 40.6 million kl

Remarks Figures derived from the results of the Echo Energy City System.

Future Development/Utilization Plans Technology development Development work on basic technologies is in its final stages. In the future, development work will focus on achieving low-cost commercial super heat pumps with the goal of recovering investments within three (3) year's time (at present, investment recovery takes between 5-6 years).

5. Geothermal Energy

R&D Overview

Development of technologies for exploring for, evaluating, drilling for, recovering and effectively utilizing the geothermal resources estimated to be so abundant in Japan.

—Development period: FY1974 on

—Total funding: ¥100 billion

1. Exploration/evaluation technologies

   [1] Comprehensive survey of geothermal resources nationwide

   Development of technology for efficiently and accurately sampling likely geothermal locales in an attempt to systematically grasp the extent of the geothermal resources present in Japan and to promote the development of this geothermal energy in a rational manner.

   [2] Study aimed at certifying technologies designed to explore for geothermal energy

   Development of optimum methods for exploring the fractured reservoir structure of the earth's crust, where the majority of Japan's geothermal reservoir exists.

   [3] Development of hydrothermal power generation system

   Development of binary cycle power generation technology for the effective use of unused medium- and high-temperature hydrothermal energy in an attempt to promote the development and utilization of geothermal energy.

   [4] Development of high-temperature solid rock power generation system

   Development of a high-temperature solid rock power generation system that extracts by means of man-made hydrothermal systems the tremendous heat energy present in high-temperature rock, and then uses this heat energy to generate power.

   [5] Development of technologies designed to study the extent of deep geothermal resources that exist below shallow geothermal resources, and efficiently recover these deep geothermal resources to increase the power-generation capacity of geothermal power plants.

Major R&D Results

1. Comprehensive survey of geothermal resources nationwide

   [1] Conducted a nationwide geothermal resources survey (FY1980-83) and prepared a sampling map of likely geothermal locations throughout the country.

   [2] Based on the results of a detailed study started in FY1984, determined the potential for geothermal resources in locations other than those pinpointed via the comprehensive survey described in (1) above, and developed optimum exploration techniques for focusing in on the most likely locations.

2. Study to certify geothermal exploration technologies

   Beginning in FY1980, carried out surface exploration and hole investigations in the well-known geothermal regions of Sengan [phonetic] and Kurikoma [phonetic], and compiled basic data required for correlation analysis of geothermal structures and exploration technology data. Used the development of a high-precision MT method to significantly enhance the economics involved in the exploration of deep geothermal resources.

3. Hydrothermal power generation

   Succeeded for the first time in the world test operating a down hole pump (50t/h, 170°C), which forms the nucleus of a binary cycle power generation system.

4. High-temperature solid rock power generation

   [1] In 1986, in a joint research effort with the United States and then West Germany, successfully completed tests on the heat extraction cycle.

   [2] In FY1991, successfully tested a long-term (90 days) heat extraction cycle in the Hijiori [phonetic] region of Yamagata Prefecture.

Current State of Utilization

There are presently nine conventional geothermal power plants (steam power generation method) in Japan producing 270,000 kW of power. Power plant name: Output (Business use)—Mori: 50,000 kW—Kuzuneda [phonetic]: 50,000 kW—Onikubi [phonetic]: 12,500 kW—Otake: 12,500 kW—Hatchobara [phonetic]: 110,000 kW (Private power generation)—Onuma: 9,500 kW—Matsugawa: 22,000 kW—Suginoi [phonetic]: 3,000 kW—Kirishima: 450 kW—Takenoyu: 105 kW Total: 270,055 kW

Current State of R&D in the Private Sector

Central Research Institute of Electric Power Industry (CRIEPI)

Currently engaged in the development of component technologies for high- temperature solid rock power generation at Osukatsucho [phonetic] in Akita Prefecture.

Anticipated Supply Potential

[1] Introduction of the results of the development of deep geothermal resources will double the volume of supply energy in the near future.

[2] Results of development efforts in the areas of binary cycle and high-temperature solid rock power generation will be gradually introduced.

[3] The latent supply potential of geothermal energy is approximately 66 million kW (Deep geothermal energy = 43 million kW; binary cycle power generation = 15 million kW; and high-temperature solid rock power generation = 7.5 million kW).

[4] Add the additional energy volume indicated in the Long-term Energy Supply/Demand Outlook under the heading "Geothermal."

Potential 21 million kW (32 million kl)

Remarks Deep geothermal energy expected to account for 40% of overall geothermal supply potential, while binary cycle power development accounts for 20% and high-temperature rock power generation for 10%.

Future Development/Utilization Plans

1. Technology development tasks

(1) Reduce costs

—Lower drilling costs

—Increase drilling efficiency by developing new drilling technology (High-efficiency drilling technology capable of withstanding high temperatures and high pressures.)

(2) Lower development risks

—Promote the development of high-precision exploration techniques

—Develop technology that will enable the effective utilization of geothermal wells (holes) that have been drilled. (Countermeasures against the attenuation of productive steam)

(3) Increase geothermal power generation capacity

—Develop unused geothermal resources Medium- and high-temperature hydrothermal resources (binary cycle power): develop technology to validate reliability and economic feasibility. High-temperature solid rock: develop practical technology Magma, etc.: develop basic technology for feasibility studies.

—Increase the capacity of existing geothermal development locations Deep geothermal resources: Develop exploration, drilling and recovery technologies.

(4) Validation tests

—Long-term continuous operation tests to validate the economical efficiency of binary cycle power generation and the reliability of the DHP and volume heat exchange systems in binary cycle power generation systems.

—Long-term continuous operation tests to validate the economic efficiency of high-temperature solid rock power generation and the heat supply capabilities of artificial reservoirs.

2. Near-term utilization plans Power plants currently scheduled to come on line. (Power plant name): (Output capacity)

—Kaminotake [phonetic]: 27,500 kW—Yamakawa: 30,000 kW—Kuzuneda [phonetic] No. 2: 30,000 kW—Ogasumi [phonetic]: 30,000 kW—Sumigawa: 50,000 kW—Yanagitsunishiyama [phonetic]: 60,000 kW—Takinoue [phonetic]: 25,000 kW—Oguni: As yet unknown Total: 232,500 kW

6. Distributed Battery Power Storage Technology

R&D Overview

Development of high-efficiency futuristic batteries and related auxiliary technologies to level user power loads as a means of relieving the day-night demand differential as well as increases in peak demand during the summer months.

—Development period: 1992-2001—Total funding: ¥14 billion

1. Development of high-efficiency futuristic batteries

Development of lithium secondary batteries possessing energy densities several times higher than those of lead batteries for use as distributed power sources and batteries for use in electric vehicles, etc.

2. Total system research R&D on the optimum capacity, environmental safety and economic efficiency of distributed battery power storage systems.

Major R&D Results

1. Large-capacity centralized systems

Research was completed in FY1991 on large-scale battery power storage systems for leveling demand loads placed on power suppliers (electric power companies). (Principal Results)—Sodium sulphur batteries—Conducted research on a 1,000 kW class pilot-plant and achieved an overall efficiency level of 76%.

2. Distributed systems—Commenced R&D on lithium secondary batteries in FY1992.

Current State of Utilization

Roughly 1,000 distributed battery power storage systems are now in use primarily in electric vehicles used as company cars by electric power companies.

Current State of R&D in the Private Sector

R&D is being pushed ahead on a variety of new types of batteries primarily for use in electric vehicles.

—Nickel hydrogen batteries

Small-size nickel hydrogen batteries have already been commercialized, but Matsushita Electric is currently developing this type of battery for use in electric vehicles.

—Sodium sulphur batteries

Yuasa Battery Co. is currently continuing development work on this type of battery started as part of the Moonlight Plan's "New Battery Power Storage Technology" project.

—Zinc-bromine batteries

Meidensha [phonetic] Co. is continuing development work on this type of battery started as part of the Moonlight Plan's "New Battery Power Storage Technology" project.

—Lithium batteries

The world's leading battery manufacturers are carrying out basic research on lithium batteries as the ultimate battery ever made.

Anticipated Supply Potential

[1] Calculate the amount of energy conserved via these new battery power storage systems by the effects of their utilization in electric vehicles

(Assuming annual mileage of 20,000 kilometers, average gasoline consumption (gas mileage) of 10 kilometers/liter and an energy conservation ratio for electric vehicles of 42%, then electric vehicle utilization will save 0.84 kiloliters of gasoline per car per year.).

[2] Of the 7.2 million automobiles expected to be operating on Japanese highways by the year 2000, a latent utilization potential of 4 million exists for electric vehicles. (Figures derived form MITI's "Electric Vehicle Popularization Plan"

Potential—1.2 million cars (10 million kl)

Remarks—Three (3) times the latent utilization potential for the year 2000.

Future Development/Utilization Plans

1. Technology development tasks

[1] Enhance battery performance

Component and prototype research is needed to achieve long-life batteries with high energy density and high output density.

[2] Utilization technology

Develop equipment necessary for the stable utilization of new types of batteries, such as optimum charging systems and residual capacity systems.

[3] Evaluation technology

Establish test evaluation methods for comprehensively evaluating battery characteristics.

2. Near-term utilization plans

[1] "Electric Vehicle Popularization Plan" (prepared by MITI)

Strive to introduce onto the market 200,000 electric vehicles primarily for business use by the year 2000 (prepared in 1991).

[2] Put together a system for promoting the widespread use of electric vehicles.

Develop battery charging stands that make effective use of night-time power, and implement a fleet testing service for electric vehicles operated by specified businesses.

—Time period: FY1992-96

—Total funding: Approximately ¥2.3 billion (Reference data)

—Steps for introducing the "Electric Vehicles Popularization Plan"

1. Basic thinking behind plan

Implement in stages policies aimed at fields targeted for popularization each period to steadily increase user groups and numbers of electric vehicles in use.

2. Overview of policies to be implemented at each step of plan.

[1] Step One (1991-93)

—Fields: Public organs and agencies at the national and local levels

—Objective: Enhance related technologies (National government will also provide assistance)

—Policy: Economic assistance (subsidies, tax breaks) and infrastructure development

[2] Step Two (1994-97)

—Fields: Public utilities (electric power companies), transportation and retail industries

—Objectives: Expand user groups and lower price of electric vehicles

—Policy: Economic assistance (tax breaks, loans) and the introduction of various incentive programs

[3] Step Three (1998-2000)

—Field: Ordinary users

—Objectives: Lower electric vehicle prices further and develop production and service technologies.

—Policy: Introduction of incentive programs and completion of infrastructure.

[4] Step Four (2001 on)

—Objective: Self-sustaining popularization that matches user demand with the supply level.

7. Ceramic Gas Turbine Engines

R&D Overview

Development of ceramic gas turbine engines using ceramic materials with outstanding heat and corrosion resistance to drastically enhance the heat efficiency (currently about 35%) of the small- and medium-sized engines employed in co-generation systems, decrease the burden on the environment and diversify the kinds of fuel used in these engines. Ceramic gas turbine engines will feature:

—Output: 300 kW

—Turbine inlet temperature: 1,350 degrees centigrade

—Heat efficiency: better then 42%

—Overall efficiency: better than 80%

—Development period: FY1988-96—Total funding: ¥16 billion

1. Development of heat-resistant ceramic members

   Development of high-precision, high-efficiency processing and parts technologies for key heat-resistant ceramic members to enhance the durability and reliability of the various component parts used in the high-temperature portions of gas turbine engines.

2. Research and development of component technologies

   Development of high-performance, low-polluting/high-load combustion component parts to enable the construction of a more compact gas turbine with all of its high-temperature component parts made of ceramics.

3. Design, prototype and operation research

   Development of a 300 kW-class ceramic gas turbine engine that features a three-stage turbine inlet temperature (900, 1,200 and 1,350°C)

Major R&D Results

1. Development of heat-resistant ceramic members

   Developed know-how related to molding methods for making heat-resistant ceramic parts that conform to the intricate shapes required for use in gas turbine engines, uniform sintering methods for thick ceramic parts and nondestructive inspection methods for ceramic parts.

2. R&D of component technologies. Carried out prototype studies for all component parts based on analysis of material and aerodynamic characteristics.

3. Design, prototype and operational research Completed prototype operational research on the primary basic model (900°C metal gas turbine engine)

Current State of Utilization

Co-generation systems are currently producing roughly 10 million kW of power using diesel engines for the most part.

Current State of R&D in the Private Sector

1. Ceramic gas turbine engines for automobiles

   The Petroleum Industry Action Center, with grants from MITI, is currently developing a 100 kW-class ceramic gas turbine engine for use in automobiles (FY1990-96).

Anticipated Supply Potential

[1] Amount of energy conserved using ceramic gas turbine engines is calculated by adding the extent to which efficiency is enhanced to the amount of heat supplied (The average power generation efficiency of existing power plants is 38%, but the overall efficiency of co-generation systems is 80%).

[2] Utilization outlook for co-generation systems (including diesel and gas turbine systems):

1988 - 10 million kW

2000 - 17.65 million kW

2010 - 24.30 million kW (Outlook of the Advisory Committee for Energy)

Potential—14 million kW (23 million kl)

Remarks—Equivalent to the increase in power generation predicted between the years 1988 and 2010.

Future Development/Utilization Plans

1. Technology development tasks

(1) Heat-resistant ceramic members.

[1] Develop manufacturing and processing technologies for high-temperature, high-strength, high-tenacity, high-corrosion-resistant ceramic members.

[2] Develop reliability evaluation technology for ceramic members

[3] Develop ceramic member design methods and application technologies that eliminate stress concentration and impact force.

(2) Component technologies

[1] Enhance the hydrodynamic efficiency and lower leakage loss of all components.

[2] Develop heat exchangers to achieve a regeneration cycle.

[3] Develop low NOx combustion technology.

(3) Engine systems

[1] Establish reliability and durability.

[2] Develop control, malfunction diagnosis and predictive systems.

8. Superconductor Power Applications Technology

R&D Overview

Development of superconductor power application equipment centered around superconductive electrical generators designed to enable the realization of highly efficient and stable power systems able to deal effectively with increased power losses and difficulties in locating power supply facilities in line with the development of large-capacity power plants and their relocation to outlying areas.

—Development period: FY1988-95

—Total funding: ¥25 billion

1. Development of superconductive electrical generators

Development of various component technologies, and the use of these component technologies to construct a 70,000 kW-class prototype superconducting generator for operational research.

2. Research and development of superconducting wire

Research and development aimed at achieving high-performance superconducting metal wire and developing superconducting wire made of oxide materials.

3. Development of refrigeration systems

Development of refrigeration equipment for long-term, stable supplies of frozen helium required to maintain superconduction.

4. Total system research

Development of test methods, as well as operational, maintenance and control technologies for superconducting generators.

Major R&D Results

Component technology development is almost complete, and plans call for the assembly of a model system and the start of tests. The principal results of research and development to date are outlined below.

1. Superconducting generator

Experimentally investigated the characteristics of superconducting magnets in a rotating state, and for the first time in the world confirmed the theoretically extremely stable operation of a superconducting generator.

2. Superconducting wire

We have completed development of metallic conductor wire materials suitable for use in superconducting generators, and developed oxide superconducting wire which is among the tops in the world in both current density and capacity.

3. Refrigeration systems

We have made headway toward the development of highly-reliable superconductor-based refrigeration systems.

Current State of Utilization

Progress on superconductors for power generation applications is still in the research and development stage worldwide, and there are as yet no examples of practical utilization.

Current State of R&D in the Private Sector

The following project is underway in the private sector:

[1] Joint research and development project by Kansai Electric Power Co., Kyoto University and the Toshiba Group on a 100KVA superconducting generator.

Anticipated Supply Potential

[1] Superconducting generators are the only turbine-based generators outside of hydroelectric power generators capable of being applied to power generation. Equipment capabilities, electric energy generation

2000: 182.1 million kW 842 billion kWh

2010: 209.6 million kW 966 billion kWh

If superconductor technology is applied to generator and power generation systems, we can expect a 4% energy conservation effect.

Potential 10 million kl

Remarks If all superconducting generators capable of being applied to power generation are in use by 2010.

Future Development/Utilization Plans

1. Technology development tasks

(1) Superconducting generator

—Operational research on a 70,000 kW-class model superconducting generator.

(2) Superconducting wire

—Development of conductors for low alternating current equipment; development of conductors with sufficiently low alternating current loss.

—Research and development of oxide materials that can be made long in length; the forming of high-temperature superconducting materials into wires.

(3) Refrigeration systems

—Equip conventional refrigeration system with higher reliability. Need for reliability equivalent to electric power equipment.

—Research and development of improved refrigeration systems. Complete elimination of the cause of helium gas pollution.

9. Coal liquefaction

R&D Overview

Development of [illegible] coal and lignite liquefaction technologies and common foundation technologies for the speedy practicalization of original liquefaction technologies geared to Japan's energy situation.

—Development period: FY1974 on

—Total development funding: Approximately ¥179.4 billion (until FY1992)

1. [illegible] coal liquefaction technology

Development of original new liquefaction processes that efficiently liquefy [illegible] coal (including [illegible] coal) found in abundance the world over into gasoline and other liquid fuels for transportation use. Currently engaged in the construction of a 150 ton/day pilot plant.

(FY1980-97)

2. Lignite liquefaction technology

Development of technology for the efficient liquefaction of the large quantities of lignite found in the Victoria region of Australia, which haven't been used to date because of this form of coal's tendency toward spontaneous combustion when it dries out. Currently compiling research results for a 50 ton/day pilot plant.

(FY1981-1993)

Common foundation technologies

Development of vital plant equipment, technologies for surveying and selecting types of coal, refining coal and protecting the environment, and applications for coal liquefaction products all geared towards the development of coal liquefaction technologies.

Major R&D Results

1. [illegible] coal liquefaction technology

Succeeded in developing the NEDOL process, which is the most advanced liquefaction process in the world possessing the following advantages:

[1] Can be applied to a wide range of different kinds of coal, from low carbon content coal to [illegible] coal;

[2] Relatively moderate reaction conditions (pressure = 170kg/cm^2, temperature = 420°C);

[3] Achieves high liquid yields of over 50% light- and medium-weight oils, for the most part.

2. Brown coal liquefaction technology Achieved the following development objectives with the 50 ton/day pilot plant.

[1] Achieved more than 50% liquified oil yields;

[2] demonstrated the long-term continuous operability of the entire process (more than 1,000 hours);

[3] Verified the development of a high-performance solvent de-ashing process (achieved ash concentrations of less than 1,000ppm);

[4] Verified the development of a fixed bed second stage hydrogenation catalyst capable of standing up to long-term operation (over 8,000 hours);

[5] Verified the development of an economical new slurry dewatering method.

Current State of Utilization

With the exception of the Republic of South Africa with its special circumstances, the countries of the world have yet to practicalize large-scale coal liquefaction technologies.

Current State of R&D in the Private Sector

Research and development efforts being carried out under the Sunshine Plan are the only such R&D projects in Japan.

Anticipated Supply Potential

[1] Technologies will begin to be introduced around the year 2010;

[2] Commercial plant output should reach 5,000 ton/day per plant (with liquid yields of 56%; equipment operation ratios of 80%; and annual output of liquefied oils amounting to roughly 840,000 kl (from roughly 1.46 million tons of coal)).

Potential

11 million kl

Remarks

Construct 66 commercial plants overseas, and import 20% of total output (of a world supply of 55.2 million kl).

Future Development/Utilization Plans

1. Technology development tasks

   Development will focus on the following items:

   [1] Low-cost development of highly reliable new reactor materials and easy upscale methods;

   [2] Development of processes capable of handling a wide variety of different kinds of coal to enable the processing of low-priced coal;

   [3] Development of improved processes and high action catalysts to lower hydrogen consumption and enhance liquified oil yields;

   [4] Development of technology to enhance process stability, curb erosion and prevent the adherence of scales, plus the establishment of operating methods to maintain high operating rates;

   [5] Increase the coal concentration of the raw slurry so as to enhance machinery efficiency and ultimately improve the process economically;

   [6] Enhance energy efficiency by developing heat recovery technologies;

   [7] Lower costs by creating high value added liquefaction residue;

   [8] Lower cost involved in commercialization by developing technologies for upgrading liquefied oils.

10. Coal Gasification

R&D Overview

Development of the technology for manufacturing hydrogen from coal and an entrained flow coal gasification power plant for achieving cleanutilization of coal and expanding its applications.

—Development period: FY1974 on

—Total funding: Approximately ¥103 billion

1. Entrained flow coal gasification power plant

   Development of coal gasification compound cycle power generation technology that is head and shoulders above conventional pulverized coal-burning thermal power generation in heat efficiency, environmental suitability and economical efficiency. Currently carrying out operational research on a 200 ton/day pilot plant (FY1986-94).

2. Technology for manufacturing hydrogen from coal

   Development of technology that will enable the low-cost, highly efficient manufacture from coal of clean-burning hydrogen for use as fuel in automobiles and aircraft. Currently carrying out operational research on a 20 ton/day pilot plant (FY1986-93).

Major R&D Results

1. Coal gasification compound cycle power generation

   [1] Fluidized bed gasification method

   Developed a 40 ton/day pilot plant (FY1978-85) and achieved 76% cold gas efficiency and 98% carbon conversion efficiency.

   [2] Entrained flow gasification method

   Developed a highly efficient power generation process (upwards of 43%) capable of using a wide variety of different types of coal.

2. Technology for manufacturing hydrogen from coal

   Developed a world-leading high efficiency process for manufacturing hydrogen from coal (more than 78% cold gas efficiency) that will make possible cheap supplies of hydrogen capable of being put to a wide variety of applications, to include use as fuels and in coal liquefaction processes. In addition, we have also made advances in component technology, such as

   —developed the world's first equalized coal distributor

   —developed heat-resistant materials capable of withstanding temperatures up to 1,800°C

   —developed two-stage slewing flow method gasification furnace.

Current State of Utilization

1. In the process of developing coal gasification compound cycle power generation technology, but still have not achieved practical utilization

2. Technology for manufacturing hydrogen from coal

   There are examples of practical equipment for manufacturing hydrogen for use as ammonia. Ubu [phonetic] ammonia

   Have been using an entrained flow gasification TEXACO furnace since 1984 (ammonia output of 1,650 ton/day)

Current State of R&D in the Private Sector

1. Coal gasification compound cycle power generation

   [1] IHI's Research Laboratory has been carrying out research on a 5 ton/day entrained flow gasification TEXACO furnace since 1987.

   [2] Coal Technology Research Institute

   Carried out research on a 40 ton/day fluidized flow gasification Yubari furnace until 1991.

   [3] Central Research Institute of Electric Power Industry (CRIEPI)

   Has been carrying out research on a 2 ton/day entrained flow gasification furnace at CRIEPI since 1982.

2. Manufacture of hydrogen from coal (Nothing in particular to report)

Anticipated Supply Potential

[1] Calculate the amount of energy conserved as the ratio of enhanced power generation efficiency (from 38% to 46%).

[2] Equipment performance outlook for coal-based thermal power plants (Denjishin [phonetic] outlook)

2000: 29.6 million kW 48.

2010: 40 million kW 49.

Potential

30 million kW (9 million kl)

Remarks

If 75% of the equipment targeted for introduction by the year 2010 is in operation.

Future Development/Utilization Plans

1. Technology development tasks

(1) Coal gasification compound cycle power generation

Enhance gas turbine inlet temperatures and lower construction costs to lower the cost of power generation below that of conventional pulverized coal thermal power generation methods.

(2) Technology for manufacturing hydrogen from coal Strive to increase plant size, reduce fixed costs and enhance operation rates to lower the cost of manufacturing hydrogen from coal to below that of producing hydrogen from petroleum-based raw materials.

11. Wind Power Generation

R&D Overview

Development of technology required for the early practicalization of large-scale wind power generation systems suited to the wind conditions that exist in Japan.

1. Development of large-scale wind power generation system

[1] Development of a large-scale 500kW-class wind power generation system to strive for enhanced economic efficiency and more effective use of land (1991 on).

[2] Development of collection-type wind power generation systems. Development of control technology for multiple wind power generation systems (1990 on).

2. Wind conditions investigations

Carry out wind conditions investigations to determine the optimum sites for locating wind power generation systems.

Major R&D Results

1. Research on 100kW-class pilot plant (FY1981-85)

Carried out operational research at a 100kW-class pilot wind power plant located on Miyakejima, and developed technology for developing a wind power plant of this class.

2. Component research for MW-class wind power generation systems

Developed component technologies necessary for achieving MW-class wind power generation systems, such as blades, rotors and control technologies.

Current State of Utilization

1. Tohoku Electric Power Company Tohoku Electric is operating a 275kW wind farm comprising five (5) wind plants at Tappimisaki in Aomori Prefecture.

2. Local energy utilization Wind plants are being used as small-scale power generation systems at various locales throughout the country.

(Major examples)

—82.5kW wind plant at the Juto [phonetic] middle school (Hokkaido) for heating purposes

—5kW wind plant operated by Daiichi Katei Denki [phonetic] (Tokyo) forlighting purposes

—3kW wind plant at the Japan Railway Hakuho [phonetic] transmission line watchhouse (Niigata) for wireless communication and lighting purposes

—16.5kW wind plant on Rokko [phonetic] Island (Hyogo) for research on system interconnection

—2.5kW wind plant at the Okinawa circuit relay site (Kagoshima) for communication power

Current State of R&D in the Private Sector

1. Mitsubishi Heavy Industries Mitsubishi Heavy Industries has commercialized a medium-scale 250kW-class wind power generation system (primarily for export).

2. Yamaha Engines Company Yamaha Engines has commercialized a small-scale (under 100kW class) 16.5kW-class wind plant (marketing it both inside and outside of Japan)

Anticipated Supply Potential

[1] For the time being, use of technologically-established small-scale (100kW or under) and medium-scale (250-kW class) wind plants will proceed ahead.

[2] Large-scale wind plants will steadily be commercialized in line with the advances in technological development.

[3] The latent potential for utilization of wind energy in Japan is roughly 4.5 million kW.

Medium- and large-scale wind power generation systems: 3.8 million kW

Small-scale wind power generation systems: 740,000 kW.

Potential 1.4 million kW (600,000kl)

Remarks 30% of latent utilization potential.

Future Development/Utilization Plans

Technology development tasks

(1) Lower costs by making larger-scale wind plants.

[1] Enhance the strength and durability of blades and other structural elements and improve system reliability to achieve large-scale individual wind plants.

[2] Development of optimum operational and system interconnection technologies as well as design technologies for creating optimum layouts and system configurations for lowering cost by using collection-type systems.

(2) Optimization of designs and operations to lower costs Create lightweight, standardized designs in an effort to rationalize production.

12. Marine Energy (Ocean Thermal Power Generation)

R&D Overview

Research and development work on ocean thermal power generation, which is expected to prove a stable source of electric power thanks to its relatively small fluctuations over time.

—Development period: 1974 on.

—Total funding: ¥3.7 billion (until FY1992)

Development of an open cycle system Implementation of basic research on open cycle systems that generate power using the sea water itself as the working medium (steam) (1990 on).

Major R&D Results

Closed cycle system

We have carried out research on various components and developed basic technologies for closed cycle ocean thermal power generation, which uses the heat of surface waters to vaporize chlorofluorocarbons and other thermal catalysts.

Current State of Utilization

There are currently no examples of applications of this technology in Japan. There is a 210kW experimental plant currently in operation in Hawaii.

Current State of R&D in the Private Sector

Ocean Thermal Power Generation Society

This society, comprised of members from electric power companies and general contractors, is carrying out research primarily in the form of feasibility studies regarding ocean thermal power generation.

Anticipated Supply Potential

The latent utilization potential for ocean thermal power generation in terms of kilowatts works out to roughly 15 million kW.

Potential 750,000kW (800,000kl)

Remarks 5% of the latent utilization potential of this technology.

Future Development/Utilization Plans

Technology development tasks

[1] Development of basic component technologies

[2] Lowering of construction costs to enhance economic efficiency

[3] Development of construction operation technologies that will make possible both environmental preservation and protection.

13. Biomass Energy

R&D Overview

Conduct of basic research for practicalizing bioenergy, which is that energy obtained by making use of the biological functions that immobilize the sun's energy.

—Development period: 1974 on

—Total funding:

1. Manufacture of hydrocarbon from plants or the highly efficient immobilization of carbon dioxide gas.
2. Growth control compounds for biomass plants
3. Effective production of photosynthetic biomass.

Major R&D Results

1. Manufacture of high performance methane gas from a film isolation compound

   Developed fermentation technology for manufacturing methane gas from polluted sludge using the anaerobic microorganisms created via the combining of a bioreactor and an isolation film.

2. Various basic research

   Carrying out various basic research concerning solar energy conversion in living organisms.

Current State of Utilization

This technology is being utilized on a small scale primarily in the field of agriculture.

—A greenhouse heating system that employs rice husks as fuel

—A humidification system in a melon cultivation hot house that uses wood fuel.

Current State of R&D in the Private Sector

Feasibility studies are being carried out on large-scale afforestation and related projects.

Anticipated Supply Potential

—Latent utilization potential of roughly 2.8 million kl.

Potential 1.4 million kl

Remarks 50% of latent utilization potential.

Future Development/Utilization Plans Technology development tasks

14. Magma Power Generation

R&D Overview

Basic research aimed at practicalizing magma power generation technology that generates power by extracting heat energy directly from magma, a source of geothermal energy supply.

—Development period:

—Total funding: Implementation of feasibility studies.

Major R&D Results

Basically, development efforts in this field are just getting underway, and as such, have yet to yield any significant achievements, with the exception perhaps of technological developments in similar areas such as high temperature solid rock power generation systems.

Current State of Utilization

Research on this technology is still in the basic stages worldwide, and there are no examples of practical utilization at this point.

Current State of R&D in the Private Sector

Nothing to speak of.

Anticipated Supply Potential

The latent utilization potential for magma generated power is estimated at roughly 800 million kW.

Potential 12 million kW (18 million kl)

Remarks 0.15% of latent utilization potential.

Future Development/Utilization Plans

Technology development tasks

(1) Implementation of feasibility studies.

(2) Development of revolutionary technologies for every stage of the process, from exploration, boring and sampling to safety, environmental protection and power generation.

Reference 2

Analysis of Achievements Contributing Toward the Simultaneous Resolution of Sustained Economic Growth and Energy/Environmental Problems Via the Sunshine and Moonlight Plans.

I. Position of Energy-related R&D Investments Under the Sunshine and Moonlight Plans

[1] Total investments in energy-related research and development in Japan during 1990 came to ¥915.0 billion (7.5% of total R&D investments for that year), of which ¥402.1 billion (43.9%) went towards R&D on nuclear power and the remaining ¥512.9 billion (56.1%) was put towards non-nuclear power-related R&D projects.

[2] The combined FY1990 budget for the Sunshine and Moonlight Plans, which are playing central roles in the research and development of renewable energy, coal conversion and energy conservation technologies, was 51.2 billion yen (¥39.6 billion for the Sunshine Plan, and ¥11.6 billion for the Moonlight Plan). This accounted for 39% of MITI's energy R&D budget of ¥129.9 billion for that fiscal year (52% of MITI's overall technology development budget), but only amounted to a mere 10% of Japan's total investments in non-nuclear energy R&D for that period.

Table 1. Investments in Energy R&D in Japan in FY1990 (in 100 millions of yen)

	Industry (Manufacturing Industry)	Research Institutes 1)	Universities	Total
Nuclear Power	827 (660)	2922	272	4021
Non-nuclear Power	2665 (2159)	2319	145	5129
Energy conservation	1882 (1693)	1754	66	3702
Renewable energies	145 (120)	86	52	283
Coal/coal conversion	172 (117)	185	8	365
Petroleum/natural gas	294 (177)	198	10	502
Electric power	172 (52)	96	9	277
Total	3492 (2819)	5241	417	9150

1) Special corporations, non-profit corporations, research cooperatives, etc.

[Source] General Affairs Agency "Report of Investigation on Energy Research" (December, 1991)

Table 2. MITI's Energy R&D Budget for FY90 (In 100 millions of yen)

Nuclear Power	Sunshine Plan	Moonlight Plan	Coal	Oil/Gas	Electric Power	Total
346	396	116	66[1)]	256	119	1299

1) Coal conversion R&D included under Sunshine Plan.

[Source] MITI "Overview of MITI's Industrial Science and Technology Policies for 1991" (March, 1991)

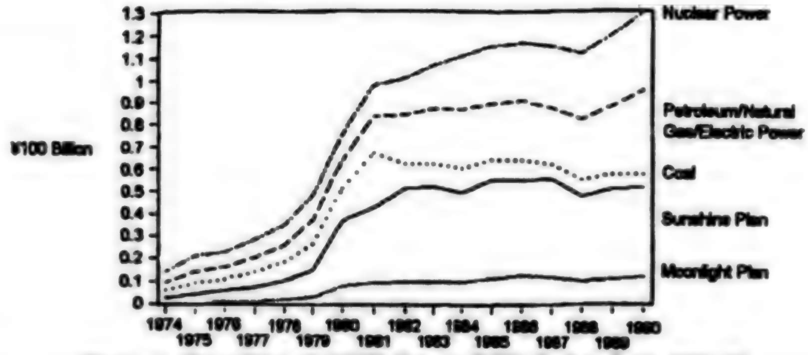


Figure 1. Transition of MITI Energy R&D Budget from 1974-90.

[Source] MITI "MITI Annual Report," "Overview of MITI Industrial Science and Technology Policies for FY91"

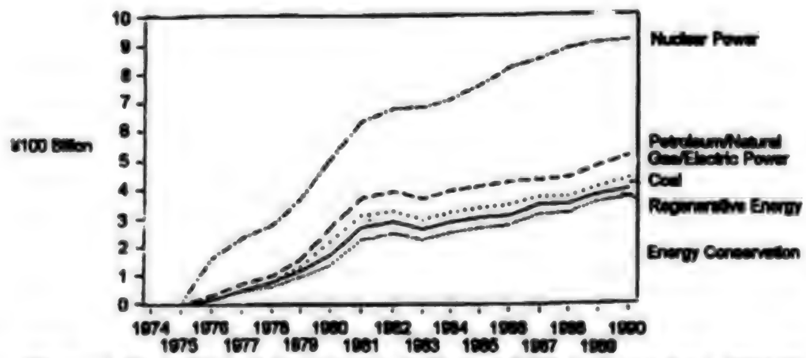


Figure 2. Transition of Investments in Energy R&D in Japan from 1974-90.

[Source] General Affairs Agency "Report of Investigation on Energy Research"

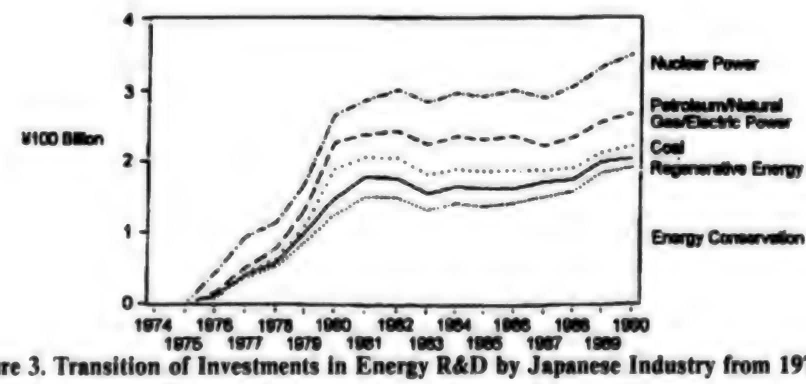


Figure 3. Transition of Investments in Energy R&D by Japanese Industry from 1974-90.

[Source] General Affairs Agency "Report of Investigation on Energy Research"

Table 3. Transition of Sunshine/Moonlight Plans' Budget Positions from 1980-90.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Sunshine Plan Budget (in 100 millions yen)	287	337	416	420	398	438	430	441	378	400	396
Moonlight Plan Budget (in 100 millions yen)	78	92	95	96	96	112	123	115	100	107	116
Sunshine/Moonlight Budgets (%) MITI Energy R&D Budget	48	44	51	48	45	48	47	48	43	42	39
Sunshine/Moonlight Budgets (%) Japanese Investment in Non-nuclear Power R&D	14	12	13	14	13	13	13	13	11	11	10

[Source] General Affairs Agency "Report on Investigation on Energy Research"

MITI "MITI's Annual Report," "Overview of MITI Industrial Science and Technology Policies for FY91"

Percentage of R&D Investment in Plants and Equipment (%)

R&D Budget for Non-energy Industry Technology (in 100 millions yen)

Energy R&D Budget (in 100 millions yen)

$$\frac{\text{RD Inv.}}{\text{Inv.}} = 0.29 \; {}_{NE}R_0^{0.16} \underset{(1.85)}{} \cdot {}_{E}R_{-2}^{0.39} \underset{(9.37)}{} \qquad \text{adj}\cdot R^2 \; 0.944 \quad \text{DW} \; 1.85$$

Analysis of Effects of MITI Energy R&D Budget on Manufacturing Industry Investments in Research and Development (1976-90)

After a two-year time lag, the energy R&D budget gave rise to strong investments in R&D by the manufacturing industry (A ¥10 billion energy R&D budget increased by 1.8% the percentage of investments in R&D made by members of the manufacturing industry. The correlation of these investments with the budget was also very high.). The immediate effect of the non-energy industry technology R&D budget on investments was great (zero time lag), but compared to the energy R&D budget, its effect on attracting investments in R&D was minimal (A similar 10 billion yen budget only increased R&D investments by 0.6%. And the correlation between these investments and the budget was relatively low.).

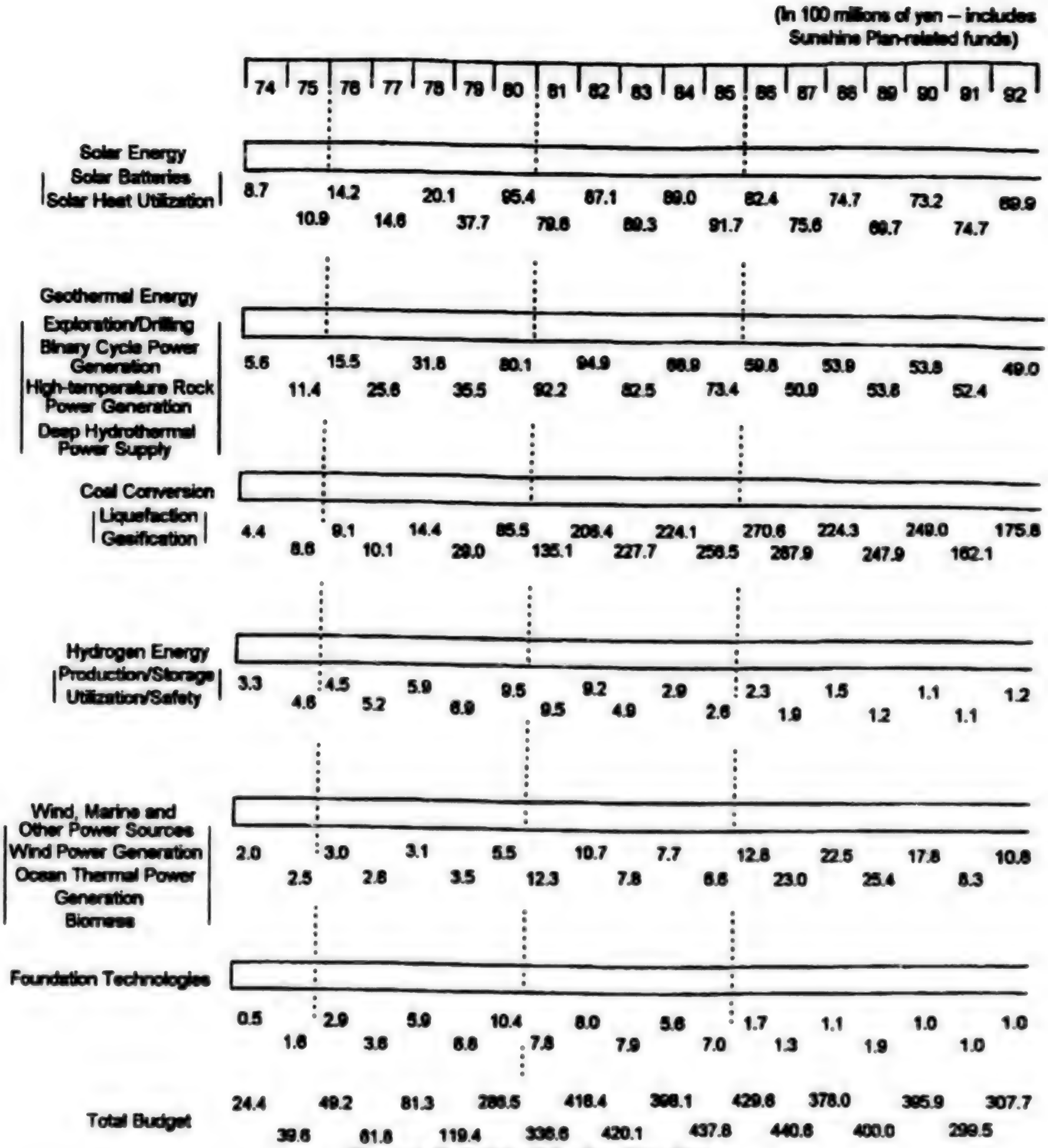


Figure 4. Evolution of the Sunshine Plan

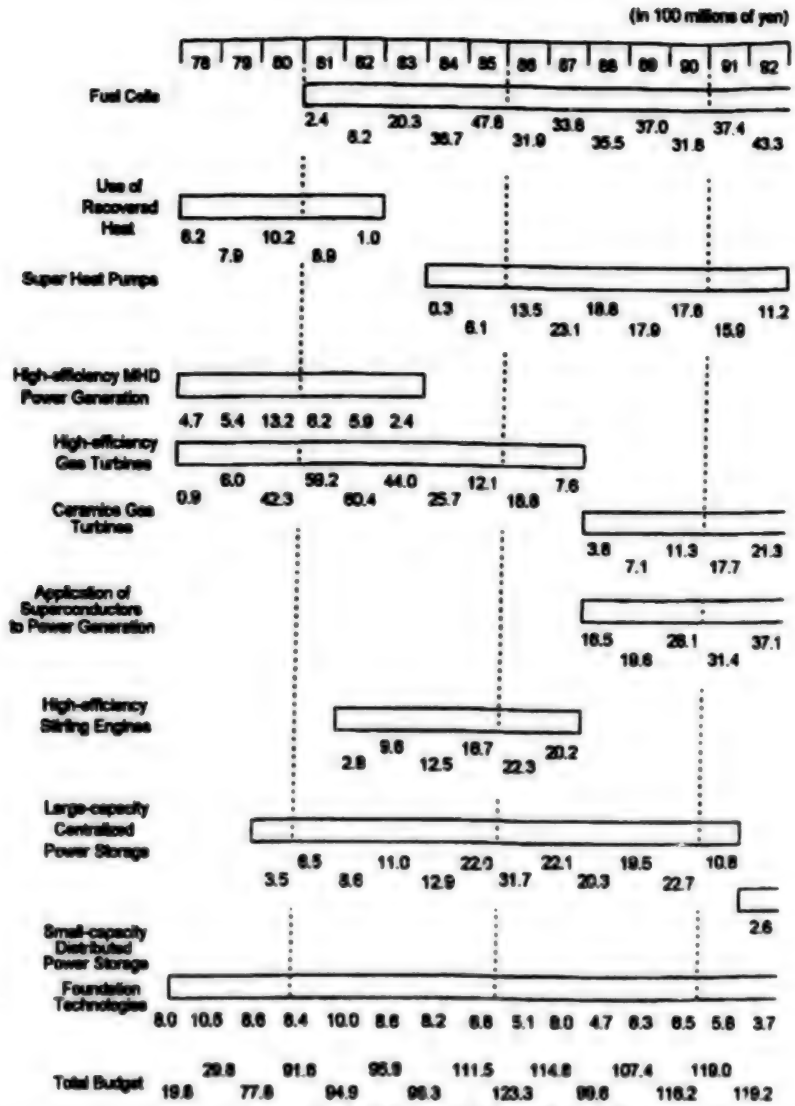


Figure 5. Evolution of Moonlight Plan

II. Roles of Sunshine and Moonlight Plans in Sparking Related Research on the Part of Industry

The combined R&D budgets for the Sunshine and Moonlight Plans works out to just 10% of Japan's total investment in non-nuclear energy R&D, but they have sparked strong R&D investments in new energies and energy conservation on the part of industry and others.

	MITI Energy R&D (1299)			Japan Energy R&D (9150)			Industry (3492)
Moonlight Plan (ML) 116	Energy Conservation	(ML)	116	Energy Conservation	(RDS)	3702	1862
Sunshine Plan (SS) 396	Hydrogen Conversion	(SH)	1				
	Renewable Energies	(SR)	146	Regenerative Energy	(RDR)	283	145
	Coal Conversion	(SC)	249				
Coal/Petroleum/Nuclear Power R&D 787 (nMS)	Coal	(MC)	66	Coal	(RDC)	365	172
	Petroleum/gas	(MOG)	256	Petroleum/gas	(RDOG)	502	294
	Electric power	(MP)	119	Electric Power	(RDP)	277	172
	Nuclear Power	(MN)	346	Nuclear Power	(RDN)	4021	827

[Source] Same as for Table 3.

(1) Inducement to Overall Energy R&D (1976-87)

		adj.R^2	DW
[Energy Conservation]	$RDS = b_0 + \underset{(19.1)}{24.0}\,ML_{-1} + \underset{(2.1)}{41.3}\,SH$	0.973	1.18
[Renewable Energies]	$RDR = b_0 + \underset{(16.4)}{2.1}\,SR$	0.961	2.84
[Solar]	$RDSS = b_0 + \underset{(15.5)}{2.0}\,SSS$	0.958	1.65
[Geothermal]	$RDG = b_0 + \underset{(6.0)}{0.8}\,SG + \underset{(2.1)}{0.2}\,SG_{-1}$	0.961	2.13
[Coal/coal Conversion]	$RDC = b_0 + \underset{(8.4)}{1.1}\,SC_{-1} + \underset{(6.1)}{1.6}\,MC$	0.920	2.21

(2) Inducement to Industry Energy R&D (1976-87)

		adj.R^2	DW
[Energy Conservation]	$RDS_1 = b_0 + \underset{(12.5)}{11.6}\,ML + \underset{(3.0)}{43.0}\,SH$	0.934	2.05
[Renewable Energies]	$RDR_1 = b_0 + \underset{(20.2)}{1.4}\,SR$	0.974	2.49
[Coal/coal Conversion]	$RDC_1 = b_0 + \underset{(7.2)}{0.7}\,SC + \underset{(4.7)}{1.1}\,MC$	0.912	1.56

Table 4. Investments in Energy Technology Development for 1990 (in 100 millions of yen)

III. Contributions Toward Increased Technology Stocks and Reduced Costs (Case of Solar Battery R&D)

As discussed above, energy R&D under the Sunshine Plan is sparking related research on the part of industry, which is giving shape to the kind of favorable cycle we are witnessing in the field of solar batteries where increased stocks of energy technology held by industry are leading to increased production of "new energy products," which in turn is steadily lowering costs, and this, in turn, is creating new demand (For example, 61% of the cost reductions realized in the field of solar batteries between 1985-90 was attributed to technology development and another 22% to increased production.).

[1978-90]

		adj.R^2	DW
(1) Stock of Solar Energy Technology in the Manufacturing Industry[1]	$Tes = b_0 + 1.4\ SSS_{-4} + 2.8\ SSS_{-5}$ (2.1) (4.6) Sunshine Plan Solar Energy Budget	0.948	1.02
(2) Solar Battery Production Output	$SCP = b_0 + 32.3\ TES$ (18.1)	0.962	1.19
(3) Solar Battery Costs	$SCC = A * Tes^{-0.82}\ SCP^{-0.22}$ (-8.06) (-7.90)	0.991	0.62

(4) Factors Behind Solar Battery Cost Reductions (Annual %)

	Reduction Ratios		Technology Stock Increases	Production Increases	Others
1978-90	-16.54	=	-7.58	-7.90	-1.06
1985-90	-12.92	=	-7.89	-2.84	-2.19

1) Solar energy technology stocks for the period t = Tes_t. $Tes_t = RDDS_{t-m} + (1-\rho)\ Tes_{t-1}$
$RDSS_{t-m}$: Solar energy R&D investments for the period $t-m$ (m = lead time from R&D to commercialization. ρ: Development technology obsolescence ratio.

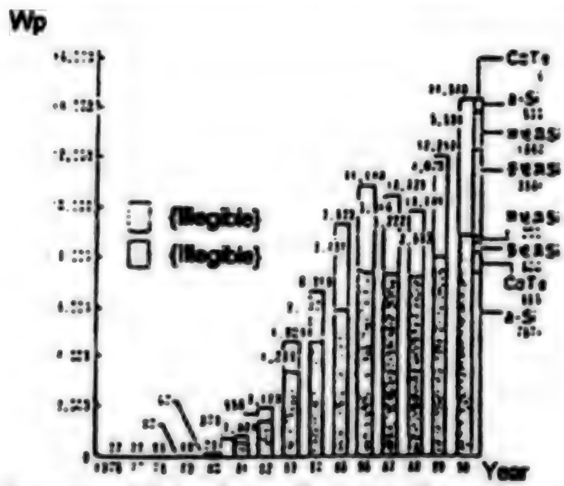


Figure 6. Transition of Solar Battery Production Output Between 1976-90
[Source] Optic Industry Technology Promotion Association

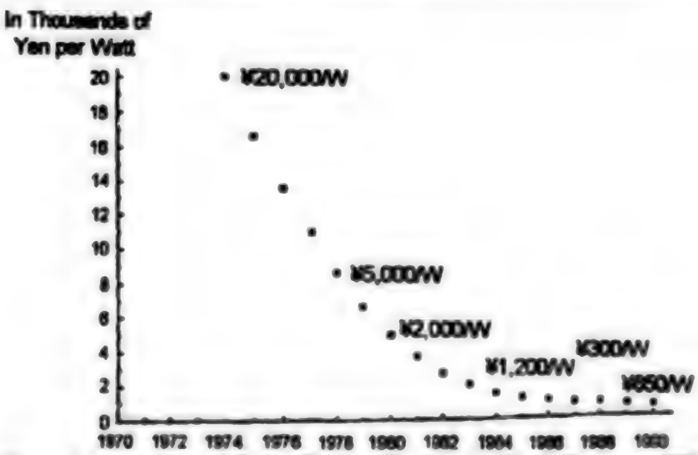


Figure 7. Transition of Solar Battery Production Costs Between 1970-90
[Source] Agency of Industrial Science and Technology (AIST)/NEDO

IV. Contributions Toward Reducing CO_2 Emissions (In the case of the manufacturing industry)

(1) Factors Contributing Toward Reduced CO_2

Fifty-eight percent (58%) of the reduction in CO_2 emissions between 1970-90 (67% between 1974-86) is attributed to energy conservation (This is followed by changes in the industrial structure (27%) and fuel conversions (12%)).

Table 5. Factors Contributing Toward the Reduction of CO_2 Emissions from the Manufacturing Industry (1970-90)

	1970-90	1971-73	1974-78	1979-82	1983-86	1987-90
Energy Conservation	58%	27%	61%	61%	83%	30%
Industrial Structure Changes	27%	6%	29%	24%	33%	30%
Fuel Conversion	12%	60%	6%	14%	-21%	35%
Others	3%	7%	4%	1%	5%	5%

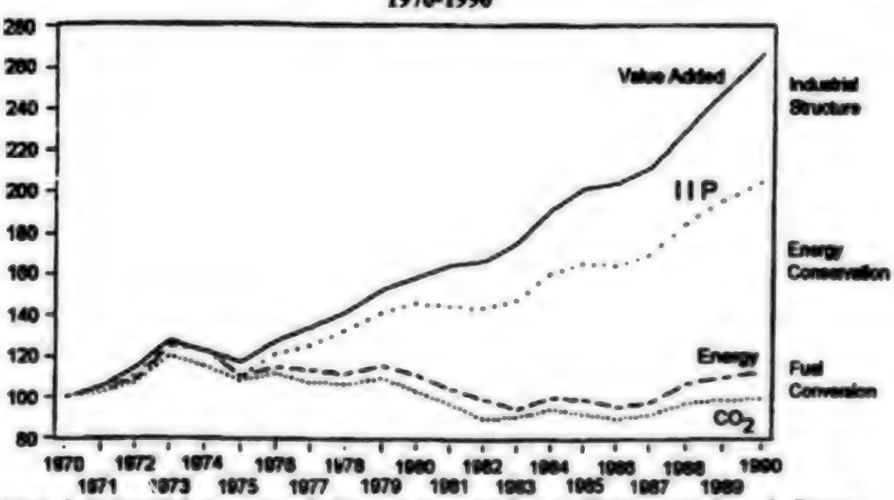
$$C = C/E \cdot E/I \cdot (V/I)^{-1} \cdot V$$

(C: Amount of CO_2 generated; E: Amount of energy consumed; I:IPP, V: Value-added base production output)

$$\Delta C/C = \underbrace{\Delta(C/E)/(C/E)}_{\text{Fuel Conversion}} + \underbrace{\Delta(E/I)/(E/I)}_{\text{Energy Conservation}} - \underbrace{\Delta(V/I)/(V/I)}_{\text{Industrial Structure Changes}} + \underbrace{\Delta V/V}_{\text{Production}}$$

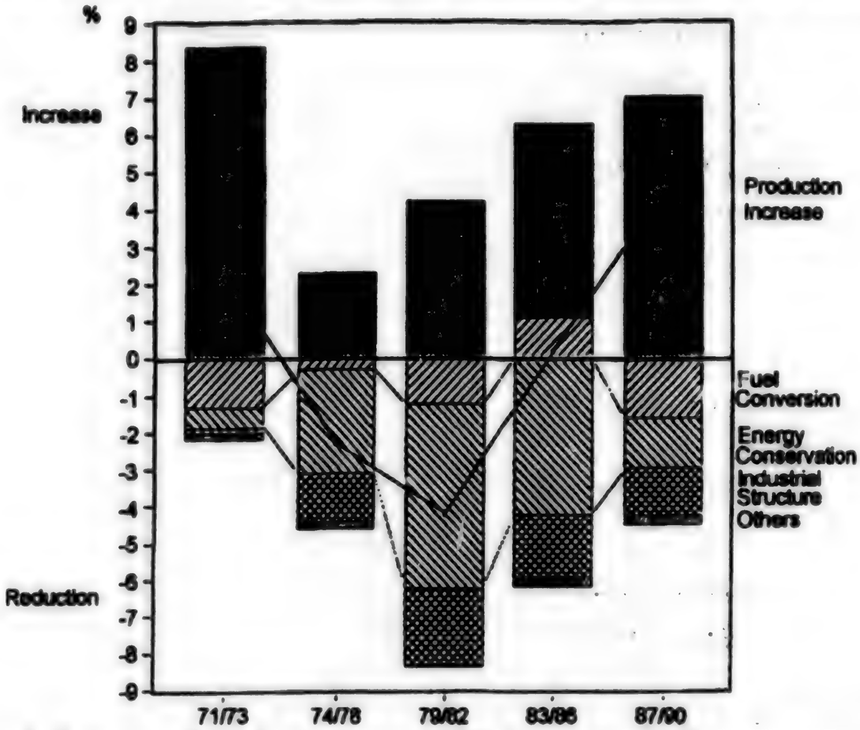
Key: 1. Energy conservation; 2. Industrial structure changes; 3. Fuel conversion; 4. Others; 5. (C:Amount of CO_2 generated, E:Amount of energy consumed, I:IIP, V:Value-added base production output); 6. Fuel conversion; 7. Energy conservation; 8. Industrial structure changes; 9. Production.

Figure 8. Transition of CO_2 Emissions, Energy Consumption and Production in the Manufacturing Industry between 1970-1990



Key: 1. Value added; 2. Industrial structure; 3. Energy conservation; 4. Fuel conversion; 5. Energy.

Figure 9. Factors Contributing Toward CO_2 Reductions in the Manufacturing Industry



Key: 1. Increase; 2. Reduction; 3. Production increase; 4. Fuel conversion; 5. Energy conservation; 6. Industrial structure; 7. Others.

Contributions of the Sunshine/Moonlight Plans Toward Energy Conservation (CO_2 Reductions)

The ability of the Sunshine and Moonlight Plans to spark industry-related energy R&D is best seen in the progress made by the manufacturing industry in energy conservation, the key factor contributing to reductions in CO_2 emissions.

[1978-90]

$$E/I = b_0 \underset{(-5.98)}{- 0.36\, SS_{-3}} \underset{(-2.06)}{- 0.54\, ML_{-1}} \underset{(-3.61)}{- 0.22\, nMS\text{-}1} \underset{(-1.73)}{- 0.22\, PE} \qquad \begin{array}{c} adj.R^2 \\ 0.989 \\ DW\ 1.49 \end{array}$$

Investments in Sunshine Plan Research	Investments in Moonlight Plan Research	Investments in Coal, Petroleum & Nuclear Research	Energy Prices

Key: 1. Investments in Sunshine Plan research; 2. Investments in Moonlight Plan research; 3. Investments in coal, petroleum and nuclear power research; 4. Energy prices.

(Note 1) The impacts of the Sunshine and Moonlight Plans on energy conservation have been no less significant than the impact that energy R&D in the manufacturing industry has had on this field (The impact on energy prices was minimal during the years 1978-90).

$$E/I = b_0 - \underset{(-9.11)}{0.37\,SS_{-3}} - \underset{(-3.04)}{0.54\,ML_{-1}} - \underset{(-3.01)}{0.14\,nMS_{-1}} - \underset{(-3.25)}{0.05\,RD_{-1}} + \underset{(0.59)}{0.07\,PE}$$

SS_{-3}	ML_{-1}	nMS_{-1}	RD_{-1}	
Investments in Sunshine Plan Research	Investments in Moonlight Plan Research	Investments in Coal, Petroleum & Nuclear Power Research	Investments in Energy R&D by the Manufacturing Industry	adj.R^2 0.995, DW 2.64

$$E/I = b_0 - \underset{(-10.60)}{0.38\,SS_{-3}} - \underset{(-3.26)}{0.49\,ML_{-1}} - \underset{(-3.27)}{0.15\,nMS_{-1}} - \underset{(-4.28)}{0.04\,RD_{-1}}$$

SS_{-3}	ML_{-1}	nMS_{-1}	RD_{-1}	
Investments in Sunshine Plan Research	Investments in Moonlight Plan Research	Investments in Coal, Petroleum & Nuclear Power Research	Investments in Energy R&D by the Manufacturing Industry	adj.R^2 0.995, DW 2.35

$$E/I = b_0 - \underset{(-10.86)}{0.16\,RD_{-2}}$$

Energy R&D by the Manufacturing Industry

adj.R^2 0.906, DW 2.10

(Note 2) The remarkable impact on energy conservation described above was made possible via the following mechanisms.

[1] In response to tightened energy supply restrictions during the energy crises, Japan substituted other essential elements of the production process for energy in order to maintain sustained economic growth (We substituted technology (T), capital (K) and non-energy intermediate materials (M) for energy).

[2] The progress in energy conservation made during this period was the result of this substitution process, with the switch from energy to technology (E to T) forming the core of the process (This subsequently resulted in increased technology stocks and improved technology levels).[1)]

[3] The switch from energy to technology led to increased stocks of energy technology,[2)] with the Sunshine and Moonlight Plans contributing toward the increases in these stocks.

[Contribution of the Sunshine and Moonlight Plans Toward Increased Energy Technology Stocks: 1977-90]

$$Te_t = (\Sigma\ RDS, RDR, RDC, RDOG, RDP, RDN)_{t-m} + (1-\rho)Te_{t-1}$$

$$Te = b_0 + \underset{(4.1)}{5.4\,SS_{-3}} + \underset{(2.9)}{20.0\,ML_{-2}} + \underset{(5.3)}{8.3\,nMS_{-1}}$$

SS_{-3}	ML_{-2}	nMS_{-1}	adj.R^2	DW
Sunshine Plan Contributions	Moonlight Plan Contributions	Contributions of Coal, Petroleum & Nuclear Power R&D	0.992	1.22

Production $Y = f(L, K, M, E, T)$

Price $C = c(Y, Pl, Pk, Pm, Pe, Pt)$

L: Labor, T: Technology stock $T_t = R_{t-m} + (1 - \rho)\, T_{t-1}$
R: R&D funds, m: Lead time from R&D to practicalization, ρ: Rate of obsolescence

These results are specified by estimating the translog (phonetic) price coefficient using the above factors, and measuring the rate of change of the ratio at which these essential elements are introduced.

This effect is specified by analyzing the elasticity value of the switch from energy to technology.

Reference 3

R&D Trends in Energy/Environmental Technology in the United States and Europe

(1) Summary

Although each nation differs as to the particular technology(ies) it is emphasizing and/or the degree to which it is increasing or decreasing its R&D budget, the trend in energy technology R&D among OECD member nations seems to be toward decreased R&D budgets for nuclear power and increased budgets for the development of alternate energies, the enhancement of energy efficiency and R&D into environmental countermeasures.

[1] Changes in Energy R&D in the United States and Europe

- During the latter part of the 1980's, budgets slated for the development of energy-related technologies decreased in line with drops in petroleum prices.
- Beginning around 1991, we have seen signs of a resurgence of interest in energy technology R&D brought about by apprehensions concerning the stability of energy supplies as a result of the Gulf War and by heightened interest in global environmental problems.
- Opportunities for advanced western nations to support the immature energy technologies of the central and eastern European countries are on the rise.

[2] Shifts in R&D Priorities

- R&D budgets for energy-related technologies did not increase much at all in 1991 compared to previous years, but we have seen a shift in R&D priorities within the scope of these limited budgets.
- There has been a steady shift in emphasis to "green energy" production, enhanced energy utilization efficiency and alternative fuels, as R&D activities related to existing fossil fuels have tended to decrease.
- Large nations are covering all the bases technologically, but smaller countries are carrying out R&D focused on specific technologies that conform to their respective needs/resources.
- Governments are in the process of withdrawing from R&D fields that should be carried out by the private sector.

[3] R&D on Environmental and Energy-related Technologies

- Emphasis is on lowering costs and eliminating technological barriers.
- As a means of diversifying sources of energy and reducing their environmental impact on the greenhouse effect, all nations are striving to development renewable energies, a trend that is leading to successes in solar battery and wind energy technologies.
- All nations are pushing forward with development work on fuel cell and heat pump technologies, and we are beginning to see some commercialization in these fields. In addition, various programs are being put together to promote R&D efforts in the field of energy conservation in industry, transportation and etc.
- Each nation in recent years has been placing emphasis on R&D efforts aimed at developing technologies to counter the effects of energy utilization on the global environment, but research on carbon dioxide immobilization technologies is still in the basic stages.
- Some countries have positioned their energy technology R&D within the broader realm of R&D tasks aimed at lowering the burden on the environment, however, the Sunshine Plan is the only example of a program that integrates R&D on energy-related technologies with that of environmental technologies, and the IEA has begun to show interest in the thinking behind this plan.

(2) R&D Trends and Policies in Major Countries

[1] United States

A. Energy Situation

—Breakdown of United States' energy sources as of 1990: petroleum 39.7%, coal 24.0%, natural gas 22.9% and nuclear power 8.4%.

—Although the United States is the world's largest energy consumer and is the largest importer of petroleum in the IEA, it supplies more than 80% of its own energy needs.

—The United States is lessening its dependence on petroleum, and striving to increase use over the long term of coal, nuclear power and renewable energies.

B. Basic Energy Policies

—Current Policies

Relaxation of government regulations

[1] Decontrol of natural gas (January 1993),

[2] Simplification of nuclear power regulations

Creation of an energy resources supply system rich in diversity

[1] Promotion of energy conservation,

[2] Support for R&D,

[3] Security for energy supplies,

[4] Emergency system for implementation in times of crisis,

[5] Support for domestic production

"National Energy Strategy" (1991)

Preparation of a four-point policy stressing

[1] energy security,

[2] the environment,

[3] electric power,

[4] the promotion of energy-related technology.

Energy policies of the new Clinton Administration

—Stresses more active involvement in new energy development, energy conservation, environmental countermeasures and international cooperation than the republican administration.

—Basis of energy policy (as per Clinton's presidential campaign)

[1] Improvement of energy utilization efficiency, promotion of energy conservation: aimed at reducing energy consumption unit requirements by 3% a year.

[2] Increased utilization of natural gas (a clean domestic energy): The deciding factor in lessening dependence on petroleum.

[3] Switch to renewable energy technologies that are easy on the environment (including clean coal).

—Maintain nuclear power at its present status, and do not approve new construction of nuclear plants for the time being.

—Promote R&D of energy-related technologies from the standpoint of strengthening the competitive power of domestic industry as well.

C. R&D Overview

—No major changes in the overall budget for R&D on energy-related technologies, but can see shifts in the development fields being emphasized.

—Stress being placed on the development of renewable energies, with the budget for this R&D increasing by 46% during the two-year period starting in 1989.

—Vital technology development fields

[1] Reform the overall state of dependence on petroleum in the transportation sector over the short haul using the following methods:

a. Enhancement of petroleum utilization efficiency.

b. Introduction of alternative fuels

c. Diversification of transportation methods.

[2] Production of domestic energy resources with an eye toward protecting the environment.

[3] Enhancement of energy efficiency and expansion of available choices of economical, clean technologies.

—Maintain the United States' position as an R&D leader in a broad range of fields related to new energies and energy conservation.

[2] United Kingdom

A. Energy Situation

—Breakdown of the United Kingdom's energy sources as of 1990: petroleum 39.0%, coal 29.5%, natural gas 22.5% and nuclear power 8.2% .... percentage of coal use was relatively high.

—Supplying its own energy needs via North Sea oil, natural gas and domestic coal.

B. Basic Energy Policies

—Based on the "Energy Plan (Green Paper)" of 1978.

[1] Sustain energy self-sufficiency using North Sea oil and natural gas, and movement toward renewed self-sufficiency based on nuclear power and coal.

[2] Effective use of coal resources

[3] Promotion of nuclear power development (Active promotion of nuclear power plants).

[4] Promotion of energy conservation

[5] Promotion of renewable energy development.

C. R&D Overview

—The energy-related R&D budget for 1991 was down 8% from 1990, and it looks like it will continue to drop in future.

—R&D programs in the non-nuclear power sector.

[1] Support for marine development projects

[2] Technology development aimed at marine safety

[3] Recycling of crude oil 2-3 times

[4] Renewable energies (wind power, tide power, high-temperature rocks, biomass and solar energy).

—Long-term strategy for renewable energies (1988).

Stimulation and promotion of the commercialization of economically superior technologies (passive solar energy technologies).

Study and select from among as-yet undeveloped technologies such as geothermal energy from high-temperature rocks, wind power and ocean thermal energy those with the highest prospects for the future.

—Looking forward to decreases in funding for nuclear power and fossil fuel R&D, and increases in funding for R&D on all other energy-related technologies.

Actively promote the development of renewable energies such as wind power.

Emphasize development of technology that will enable the clean use of domestically-produced coal.

[3] Germany

A. Energy Situation

—Breakdown of Germany's energy sources as of 1990: petroleum 40.9%, coal 26.7%, natural gas 17.3% and nuclear power 13.8%.

—Reliance on imports is high: 95% for petroleum, roughly 50% overall.

B. Basic Energy Policies

—According to announcements by the Federal Economics Ministry in 1986:

[1] Secure economical and efficient supplies of energy.

[2] Diversify sources of energy supplies and lower dependence on petroleum.

[3] Diversify sources of energy (especially petroleum) imports.

[4] Make energy consumption more efficient.

[5] Improve the system for dealing with crises.

[6] Suppress environmental pollution associated with the supply and use of energies.

—Energy policies for a unified Germany (1991)

Basically in line with previous energy policies, but rather ambiguous as far as the consensus on coal and nuclear power, the two main alternatives to petroleum, are concerned.

C. R&D Overview

—R&D budget down slightly in line with cutbacks in nuclear power budgets.

—Objectives of Third R&D Program (adopted 1989; revised 1991).

[1] Further development of present energies.

[2] Development of energy sources that do not emit CO_2.

[3] Conversion to efficient energies, and development of energy conservation technologies.

[4] Preparation of firm strategy for reducing greenhouse effect gases.

[5] Strive to secure energy supplies without damaging the environment

To expand renewable energy programs.

—Reduce research budgets for sources of fossil energies and nuclear power.

Increase funds for renewable energies and energy conservation.

[4] France

A. Energy Situation

—Breakdown of France's energy sources as of 1990: petroleum 40.3%, nuclear power 37.1%, natural gas 11.3% and coal 9.6%....High percentage of nuclear power.

—High reliance on imports: 96% for petroleum and 53% overall.

B. Basic Energy Policies

—Energy objectives specified in the "Seventh Socioeconomic Development Plan" (1975).

[1] Reduce reliance on petroleum to 40%.

[2] Maintain current state of petroleum consumption.

[3] Accelerate nuclear power program (All electric power generation from nuclear power).

[4] Promotion of energy conservation and a roughly 15% savings in energy consumption.

[5] Promote the development and use of new energies.

—"Energy 2010" (1990)

[1] Lower the tendency toward nuclear power.

[2] Introduction of alternative fuels into the transportation sector.

C. R&D Overview

—Policy statements in the Branner (phonetic) Report (1989).

[1] Lighten the value-added tax burden on energy technology equipment that is highly effective at conserving energy.

[2] Lighten the value-added tax burden on automobiles with small displacement engines.

[3] Increased budget for energy conservation related research.

[4] Increased R&D budgets for new and renewable energies

—Despite the statements made in the report, France's energy policies thereafter showed little change, and R&D budgets have remained practically the same.

—Place more emphasis on energy conservation technology which can be expected to show immediate results, rather than on long-range new energy technology development.

[5] Canada

A. Energy Situation

—Breakdown of Canada's energy sources as of 1990: petroleum 36.8%, natural gas 26.4%, hydroelectric/geothermal 12.1%, coal 11.6% and nuclear power 9.0%.

—Canada has abundant energy resources, including natural energies, and overall is an energy exporter.

B. Basic Energy Policies

—Promote the mining and development of vast buried energy resources and establish an energy self-sufficiency system.

—Strive to break free of petroleum imports by improving energy conservation and efficiency and developing diverse energy resources.

—Place more importance on nuclear power as a source of energy.

C. R&D Overview

—National Energy Research and Development Plan (1988).

Shift emphasis from fossil fuels to research and development aimed at improving energy efficiency, developing alternate energy sources and lowering the adverse affects on the environment.

—Being rich in energy resources, the desire to develop renewable energies in Canada is rather low, but they are ardently pursuing basic research in hydrogen energy. Canada is also promoting the development of nuclear power centering on CANDU (a natural uranium/heavy water reactor).

[6] Italy

A. Energy Situation

—Breakdown of Italy's energy sources as of 1990: petroleum 59.2%, natural gas 25.2%, coal 9.5% and nuclear power 0.0%.

—High reliance on petroleum, and highly dependent on imports for its supply.

B. Basic Energy Policies

—A national referendum in 1987 led to the renouncing of nuclear power for the time being.

—National Energy Plan (PEN: 1988) ... Prepared based on the above cited referendum results.

[1] Develop new technologies to reinforce various energy conservation efforts.

[2] Preserve the environment.

[3] Develop domestic energy resources (Petroleum, natural gas, water and geothermal).

[4] Diversify suppliers of energy resources, and reduce dependence on overseas suppliers.

[5] Further strengthen competitiveness of energy production system.

C. R&D Overview

—Government R&D budgets are dropping off slightly, but those of public enterprises have increased.

—R&D priorities

Environmental preservation technologies: CO_2 control, absorption and conversion technologies.

Development of renewable energies: hydroelectric, geothermal, wind power and PV modules.

Coal-related technologies: CWM, combustion technologies.

Nuclear fusion research.

—As a result of announcements under PEN, there are prospects for increases in research funds for technologies other than nuclear fission technologies.

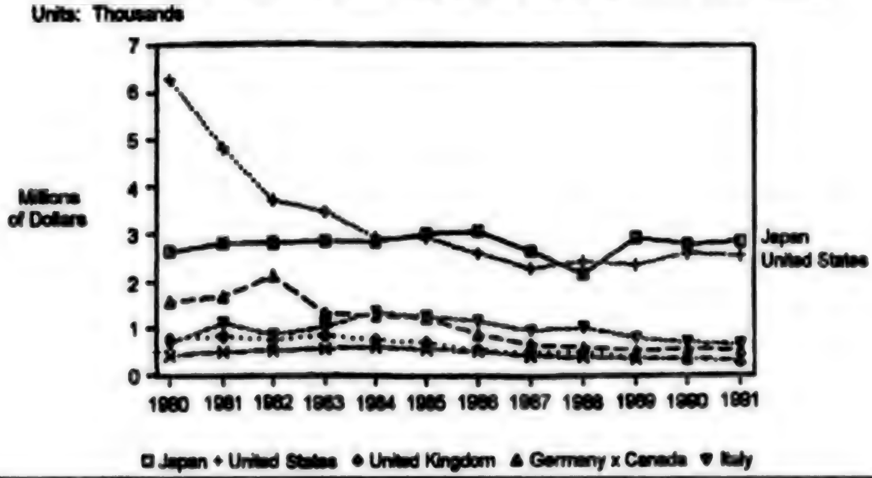
[7] Overview of R&D Budgets of Seven Summit Nations

A. Transitions of Government Energy R&D Budgets and Their Breakdowns

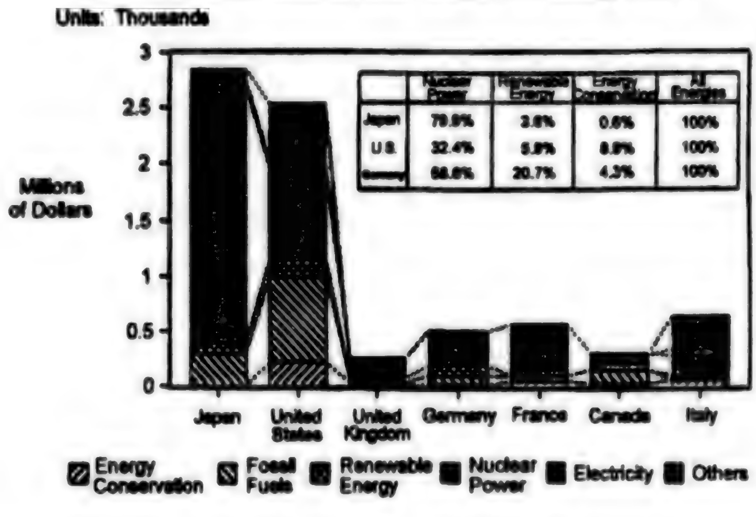
a. Government budgets for energy-related research in the seven (7) leading economic nations have remained relatively unchanged in recent years, with Japan (¥383 billion) and the United States, whose budget exceeded 2.5 billion dollars, heads and shoulders above the others in this category.

b. Broken down by research field, the percentage of funding going toward research in nuclear energy has risen across the board, with France and Japan jointly accounting for around 80 percent of the total (Japan alone has invested over 2.0 billion dollars in nuclear energy research). The United States, Germany and Japan, in that order, lead the pack in terms of overall budgets slated for research on renewable energies, but Japan comes in fourth place in this field after Germany, the United Kingdom and Italy when it comes to actual R&D funding. And Japan's budget for energy conservation research is overwhelmingly the lowest of any of the other nations at less than 1% (R&D on fuel cell power generation technology under the auspices of the Moonlight Plan falls into a different category from electric energy conservation.).

Transition of Government R&D Budgets for Energy (In 1991 U.S. dollars)



Breakdown of Government R&D Budgets for Energy (1991)



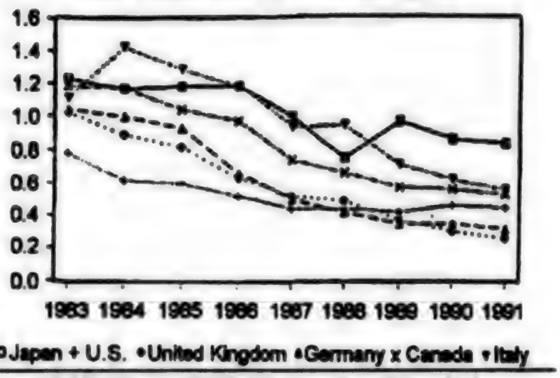
B. Transition of Government Energy R&D Budgets as a Percentage of GDP

a. The leading nations in terms of R&D budgets as a percentage of GDP for all forms of energy are Japan, Italy and Canada, respectively, but they are all showing a tendency to decline.

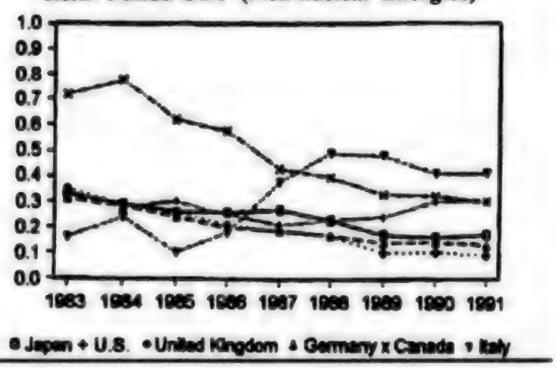
b. Broken down by energy field, Japan's 0.67 (as of FY1991; units: 0.01% [here and below]) is twice that of any of the other leading nations, and its 0.17 for non-nuclear energy R&D budgets puts Japan in fourth place after Italy, Canada and the United States, in that order.

c. Germany is attracting attention for its tendency to increase its government R&D budget as a percentage of GDP for renewable energies, while Japan, with its 0.03 is on a par with other nations in this category.

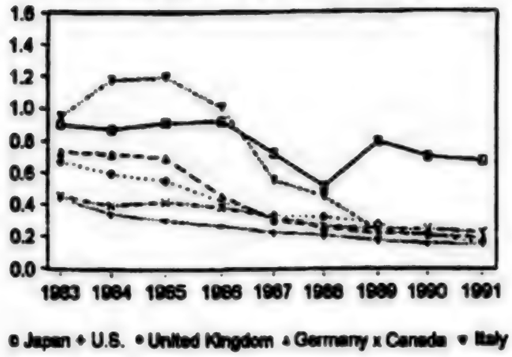
R&D Funds/GDP (For All Energies)



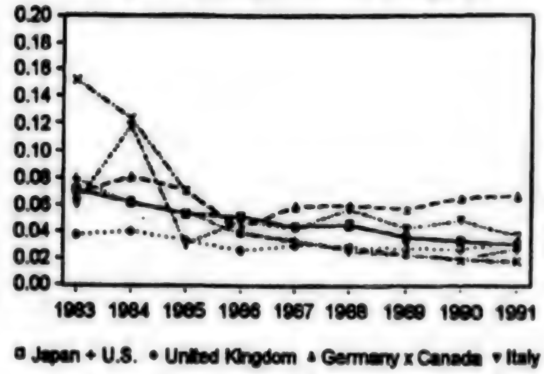
R&D Funds/GDP (Non-nuclear Energies)



R&D Funds/GDP (Nuclear Power)



R&D Funds/GDP (Renewable Energies)



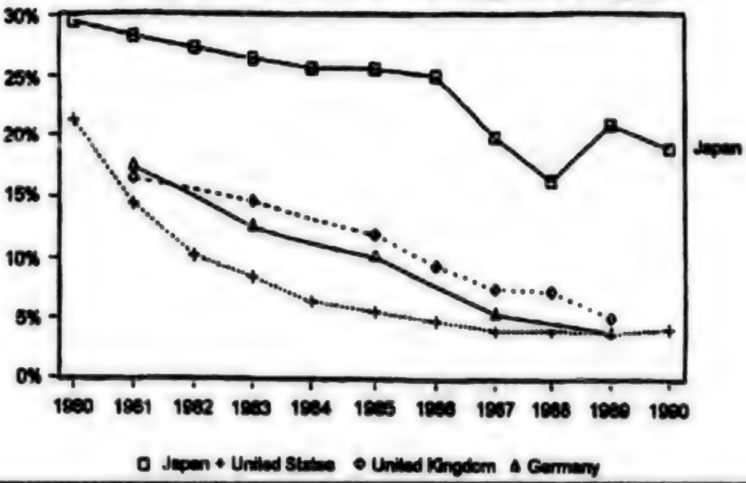
(Units: 0.01%)

	All Energies	Nuclear Power	Non-nuclear Energies	Renewable Energies (Including Solar Power)
Japan	0.84	0.67	0.17	0.03 (0.016)
United States	0.45	0.15	0.30	0.03 (0.012)
Germany	0.32	0.19	0.13	0.07 (0.051)

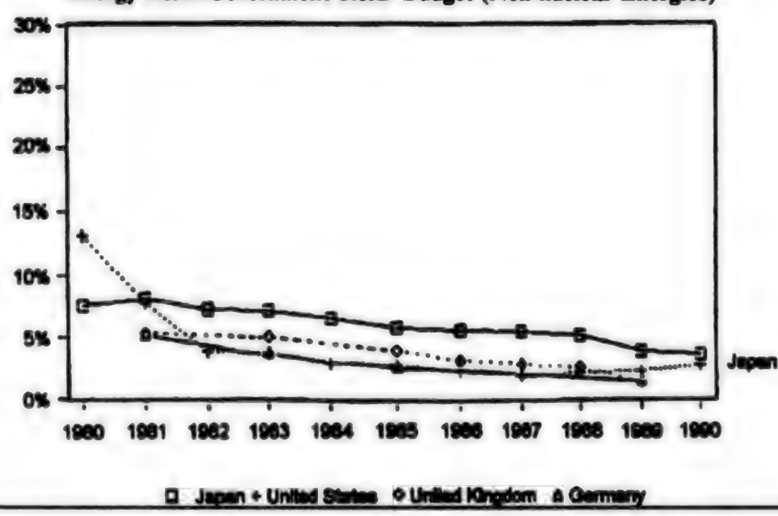
C. Transition of Energy-related R&D Budgets as a Percentage of Government R&D Budgets

Japan's percentage of the government R&D budget allotted to its energy R&D budget far surpasses that of the other leading nations (four times those of the United States and Germany), but this is attributable almost entirely to Japan's nuclear power R&D budget. In the area of non-nuclear energy R&D budgets, Japan's percentage of its government R&D budget works out to just 3.5%, putting it on practically the same level with the United States, the United Kingdom and Germany.

Energy R&D/Government R&D Budget (All Energies)



Energy R&D/Government R&D Budget (Non-nuclear Energies)



(3) Comparison and Contrast of Current State of R&D in the Leading Nations

[1] Japan leads the rest of the world in the areas of fuel cell power generation technology, heat pump technology and CO_2 immobilization technology, and has attained technological prowess on a par with other world leaders in the areas of renewable energies and coal energy.

[2] The United States possesses the most advanced technologies in the fields of renewable energies and coal energy, and Germany's superconductive electrical generator technology is tops in the world.

[3] Together with the United States and Germany, Japan is playing a leading role in the research and development of energy-related technologies, making it vital that Japan carry out its R&D activities efficiently, and exchange information and cooperate in research projects with other nations.

	Solar Energy	Thermal Energy	Coal Energy	Hydrogen Energy	Wind Power/Ocean Thermal Energy
Japan	Photovoltaic power generation: developing low cost solar battery manufacturing technologies and ultra-high efficiency solar battery technology, and are in the process of either constructing or operationally researching photovoltaic power generation systems (eight (8) systems). Solar heating and cooling: Have completed research on experimental buildings for four (4) consumer solar heating/cooling systems; have completed research on eight (8) industrial systems, and are currently developing component technologies to enhance the performance of these systems.	Steam power generation: currently producing roughly 270,000kW of power from 10 steam power plants nationwide. Hydrothermal power generation: carrying out R&D on a 10,000kW class binary cycle power plant. High temperature rock power generation: developing component technologies domestically. Took part in joint research with the United States and Germany until September 1986 (Germany participated until September 1985). Deep hydrothermal energy: completed research on extraction and reduction testing.	High calorie coal gasification: Finished operational research on a 7,000Nm^3 per day plant. Hydrogen production: Currently carrying out operational research on a 20 ton/day plant. Coal gasification power generation: Finished operational research on a 40 ton/day fluidized flow gasification plant, and currently carrying out operational research on a 200 ton/day entrained flow gasification plant. Coal liquefaction: compiling results obtained from operation of 50 ton/day lignite liquefaction plant in Victoria, Australia; Currently constructing 150 ton/day [illegible] coal liquefaction plant.	Electrolytic method: conducting basic research on a solid high polymer electrolytic water method and a high temperature steam electrolytic method. Thermochemical method: Completed basic research. Transport/storage method: currently conducting research and development work. Hydrogen engine: conducting research and development work.	Wind power generation: Completed development of a 100kW plant, and in the process of developing a 500kW plant. Ocean thermal power generation: Conducting basic research.
United States	Solar thermal power generation: operating a roughly 350,000kW plant commercially. Photovoltaic power generation: started the Solar 2000 Project (1,000MW and over); Started the PVMaT Project.; PVUSA Project (for electric power), Currently operating two (2) 3,000kW, two (2) 2,000kW and two (2) 1,000kW plants. Solar heating and cooling: in the process of constructing and/or operating a number of experimental and demonstration systems.	Steam power generation: Currently producing 2.64 million kW of power. hydrothermal power generation: Currently producing 200,000kW of power. High temperature rock power generation: succeeded in heat extraction of 9,000kW of heat output; Took part in joint research with Japan and Germany (Germany until September 1985; Japan until September 1986) on a 20,000-50,000kW heat output system (4000M class).	High calorie coal gasification: Currently operating 3.5 million Nm^3 per day (12,700 tons per day) plant. Coal gasification power generation: Currently operating 1,000 ton/day plant (Coolwater). Coal liquefaction: Completed operation of a 30 ton/day plant (SRCII); Completed operation of 200 ton/day plant (H-COAL); Completed operation of a 250 ton/day plant (EDS); Carrying out research to improve the liquefaction process.	Electrolytic method: Currently developing a solid high polymer electrolytic water method; Doing basic research on a high temperature steam electrolytic method. Thermochemical method: Doing basic research. Transport/storage method: Doing basic research.	Wind power generation: Operating a 4000kW plant. Ocean thermal power generation: Finished experiments on 50kW plant (Mini-OTEC); Completed experiments on a 1,000kW heat loop experimental plant (OTEC-I); Planning the development of a 40MW plant; Planning the development of a 165kW open cycle plant.

(Continued)

	Solar Energy	Thermal Energy	Coal Energy	Hydrogen Energy	Wind Power/Ocean Thermal Energy
Germany	Photovoltaic power generation: Currently doing research on continuous manufacturing technologies for solar batteries; Started the 1,000 Loop Project; Developing technologies for developing countries; Planning a 1MW photovoltaic power generation project; Currently operating 300kW, 330kW and 340kW plants. Solar heating and cooling: developing a passive solar device.	High temperature rock power generation: Took part in joint research with the United States and Japan until September 1985. Has completed domestic R&D (3000M class); Currently carrying out joint research with the United Kingdom and France (2600M class).	High calorie coal gasification: Completed operation of a 150 ton/day plant (Ruhr 100). Coal gasification power generation: Completed operational research on a 170,000kW (roughly 1,500 ton/day) plant. Coal liquefaction: completed operation of a 200 ton/day plant (New IG), are in the midst of operational research on a [illegible] decomposition plant, and have completed conceptual design work on a 2,500 ton/day demonstration plant.	Electrolytic method: Conducting basic research on a high temperature steam electrolytic method; Developing an alkaline water electrolytic method. Thermochemical method: Conducting basic research. Transport/storage method: In the midst of research and development work. Hydrogen engine: In the midst of research and development.	Wind power generation: Planning to construct a 3,000kW plant; Developing a 1,200kW plant.
France	Solar thermal power generation: Finished operational research on a 2,500kW plant. Photovoltaic power generation: researching methods of making solar batteries less expensive. Solar heating and cooling: operationally researching an experimental home.	High temperature rock power generation: carrying out joint research with the United Kingdom and Germany (2600M class). Deep hydrothermal energy: currently supplying local hot water and heat in 46 regions of the country.		Electrolytic method: Developing alkaline water electrolytic method; Doing basic research on a solid high polymer electrolytic water method. Hydrogen engine: In the midst of research and development.	Ocean thermal power generation: Completed basic design and economic evaluation on a 5MW plant.
United Kingdom	Photovoltaic power generation: Carrying out basic research. Solar heating and cooling: doing research primarily on solar hot water supply systems.	High temperature rock power generation: Engaged in R&D (2600M class).	Coal gasification: Currently operating 550 ton/day plant. Coal liquefaction: Currently operating a 2.5 ton/day plant.	Electrolytic method: Doing basic research.	Wind power generation: Test operating a 3,000kW plant.
Others	Solar thermal power generation: The EC is conducting operational research on a 1,000kW class plant in Italy; The IEA is conducting operational research on two (2) 500kW class heating plants in Spain; Spain is operationally researching a 1,000kW plant. Photovoltaic power generation: Italy is operating a 300kW plant and developing a 100kW plant for electric power; Switzerland is conducting its Energy 2000 Project (manufacturing technology). Solar heating and cooling: The Netherlands, Australia, Austria and Sweden among others are researching solar heating systems.	Steam power generation: the following countries are currently producing the cited amounts of power: Philippines (890,000kW), Mexico (700,000kW), Italy (570,000kW), New Zealand (280,000kW), El Salvador (160,000kW), Indonesia (140,000kW), Kenya (50,000kW), Iceland (50,000kW) and Nicaragua (70,000kW). Multipurpose utilization: China, Russia and India are currently using deep hydrothermal energy for local heating purposes.	Republic of South Africa: currently operating SASOL I (roughly 15,000 ton/day), SASOL II (roughly 42,000 ton/day) and SASOL III (roughly 42,000 ton/day) using indirect liquefaction method. Canada: Currently operating a 0.25 ton/day plant using a direct liquefaction method (Co-processing method). Russia: Currently operating a 5 ton/day plant using direct liquefaction method.	Electrolytic method: Alkaline water electrolytic plants in operation in Canada and Brazil, etc.; Switzerland conducting basic research on solid high polymer electrolytic water method.	Wind power generation: Sweden currently operating a 3,000kW plant; Denmark is operating a 2,000kW plant; Canada is operating a 4,000kW plant; The Netherlands is operating a 1,000kW plant; Italy is developing a 1,500kW plant; Spain is operating a 1,200kW plant; Norway is operating a 1,200kW plant.

	Fuel Cell Power Generation Technology	Heat Pumps	Superconductor Power Applications Technology	Ceramic Gas Turbine	Secondary Battery Development
Japan	Phosphoric acid fuel cells: Have developed basic plant technologies. Will soon commercialize a 500kW or under on-site plant. Conducting research aimed at practicalizing plant with larger capacities than 500kW. Fused carbonate fuel cells: Developing 100kW stack and auxiliary equipment aimed at realizing a 1,000kW pilot plant. Solid electrolyte fuel cells: In the process of researching component technologies. Developed several 100kW stacks mainly of the flat plate type.	—In process of developing 1,000kW heat pump (super heat pump). For heating purposes only: 85°C, COP6-8; For both heating and cooling: 7/45°C, COP6-8; For high temperature uses: 150/300°C, COP3. —Chemical heat accumulator technologies. Heat accumulator temperatures: 150-200°C; Cold heat accumulation: less than 10°C. (Most advanced technology level in the world)	Superconductive electrical generator: Developing a 7kW model superconducting generator in line with plans for a 200,000kW pilot superconducting generator. Superconducting magnetic energy storage (SMES) equipment: Developing component technologies for 100kW storage facilities. Superconducting materials: Developing NbTi and Nb_3Sn for alternating current use.	(For power generation) Manufacturing a prototype of a 300kW basic ceramic gas turbine (TIT 1,200°C).	Na/S, Zn/Br batteries: Completed development of batteries for a 1,000kW pilot plant (first in the world). Have commenced development of lithium batteries with higher energy density and longer life than H4 batteries. Applications: Fixed type (buildings, homes); mobile uses (electric vehicles).
United States	Phosphoric acid fuel cells: Finished developing basic plant technologies. On verge of commercializing 200kW plant. Not much activity on large-scale plants. Fused carbonate fuel cells: Developed 70kW stack and aiming to develop pilot plant. Solid electrolyte fuel cells: Developed cylindrical 25kW module. Developing several flat plate type 10W stacks.	Currently developing a special compact heat pump with a high coefficient of performance (a combination of a compression system and heat accumulator). Chemical system: developing an improved liquid chemical/gas and solid/gas heat pump; Brayton cycle solvent recovery system: Developing a reverse Brayton cycle heat pump; Magnetic system: Developing a heat pump that uses a superconducting magnet.	Superconductive electrical generator: Developing a 10,000kW superconducting generator at MIT. SMES: Developing a 20,000kWh test model SMES in line with plans to realize a large-scale SMES under the auspices of DOE.	(For automobiles) 1979-87: Carried out the AGT Project (an advanced gas turbine development project), during which a prototype engine was constructed. 1987-92: conducted the ATTAP Project (a project aimed at developing technology for an advanced ceramic gas turbine) and completed an engine for use as a test bed in the evaluation of ceramic parts. The project was extended an additional year, and plans for the future are being put together.	Promoting projects centered around a joint government/private sector project (USABC). Application: electric vehicles; Targets: Have decided on Ni/H_2 and lithium batteries, and are studying Na/S and other potential batteries.
Germany	Phosphoric acid fuel cells: In process of testing a 200kW American plant. Fused carbonate fuel cells: Introducing American stack technology. Aim to develop 20kW stack. Solid electrolyte fuel cells: Developing 2kW cylindrical module and several 10W flat-plate stacks. Other: researching alkaline and solid high polymer fuel cells.	Developing a air/water heat pump (vibrant style) capable of heat output of 615kW.	Superconductive electrical generator: Siemens and KWU are developing a 120,000kW superconducting generator. SMES: Munich Institute of Technology has developed a 4kWh SMES, and the Karl Slugo (phonetic) Research Institute is putting together conceptual designs for a 100,000kWh SMES.	Germany, France and Sweden. (For automobiles) These three (3) countries were planning the development of a 100kW ceramic gas turbine as a joint research project, but it was canceled. They are now scheduled to put together plans for the future this fall.	The ABB company is developing for commercialization an Na/S battery for electric vehicles.

(Continued)

	Fuel Cell Power Generation Technology	Heat Pumps	Superconductor Power Applications Technology	Ceramic Gas Turbine	Secondary Battery Development
France	Phosphoric acid fuel cells: Public gas companies showing some interest. Other: Not much concrete activity.	Developing heat pumps primarily for industrial use.	Superconductive electrical generator: Developing a totally superconductive electrical generator. Superconductor materials: Developing NbTi multi-core wire material for AC use.		SAFT company developing lead batteries and Ni/Cd batteries for electric vehicles.
United Kingdom	Solid electrolyte and solid high polymer fuel cells: Have begun undertaking basic research.	Compression system: Developing low cost compressors, and researching heat pump applications in drying and distillation processes.			CSPL company is developing Na/S batteries for electric vehicles.
Others	Phosphoric acid fuel cells: Sweden, Italy, Switzerland and Spain are test operating plants made in the United States and Japan. Fused carbonate fuel cells: The Netherlands and Italy are developing stacks ranging from several kW to 10kW in output. Solid electrolyte and solid high polymer fuel cells: The Netherlands, Switzerland, Norway and Denmark are undertaking basic research. Other: Belgium, The Netherlands and Italy are researching alkaline and solid high polymer fuel cells.	Sweden: Developing improved heat pump technology. Norway: Developing a new generation of heat pumps (COP5-6). Italy: Developing improved absorption style heat pumps. Netherlands: developing improved absorption style heat pumps. Switzerland: developing a free piston Stirling engine heat pump.	Superconductive electrical generator: The former Soviet Union was developing a 300,000kW superconducting generator, and Austria is currently testing a 2,000kW superconducting generator. SMES: Switzerland is developing a 50kWh SMES, the former Soviet Union was developing a 28kWh SMES and Canada is developing an 83kWh SMES.		Canada: Would like to take part in America's USABC project.

	Rarefied Combustion Denitration Catalyst Technology	Biological CO_2 Immobilization	Chemical CO_2 Immobilization	CO_2 Storage/Disposal (Oceans/Underground)	Alternative Substances to CFCs
Japan	National research institutes are carrying out basic research on oxide catalysts, piolite (phonetic) catalysts and metal catalysts. Automobile makers are also engaged in basic research on these catalysts. (Most advanced level of technology in the world.)	Developing technologies for immobilizing and effectively using CO_2 found in bacteria/algae (RITE). Microalgae: The various power companies, CRIEPI and the Tokyo University of Agriculture and Technology are carrying out basic tests. Spirillina (phonetic): currently producing for commercial use (yearly output of 60 tons from 30,000m^2 pond culture.) Breeding/photosynthesis mechanism: Carrying out basic research.	Absorption/attachment method: Power companies are leading the way in development aimed at enhancing performance. Film isolation method: Developing a method for making methanol by reacting concentrated CO_2 with hydrogen (RITE).	Ocean disposal: Carrying out basic research at national research institutes. Deep ocean bottom storage: CRIEPI has begun basic research related to evaluating achievability.	Third generation CFCs: Developing a new refrigerant for use in compression-type heat pumps as part of a five-year plan that began in 1990 (RITE).
United States	GM, Ford and other U.S. automakers are engaged in basic research.	Microalgae: Pond cultures of several 100 hectares. Breeding/photosynthesis mechanism: Carrying out basic research.	Does not see the merits of chemical immobilization methods; R&D in this area low keyed. Film isolation: developing a methane/CO_2 isolation film. Catalysts: Developing a catalyst for synthesizing methanol using CO/H_2.	Prevalent opinion is that it is not cost effective, and so the U.S. is not carrying out R&D in this area (*).	Third generation CFCs: Universities are leading R&D using funds from EPA. Very likely that CFC manufacturers are also doing research in this area. Second generation CFCs: Under development.
Germany	Volkswagen, Mercedes Benz and other German automakers are carrying out basic research.	Microalgae: Researching culture reactors.	Putting more emphasis on acid rain than the problem of CO_2 (DeNOX, DeSOX). Catalysts: Pushing forward with R&D on synthesizing methanol using catalytic hydrogenation and electrochemical reduction. Hydrogen absorbing alloys: Full-scale research.	Ocean disposal: Developing a global distribution model.	Second generation CFCs: Under development.
France	CNRS (catalyst research institute) is engaged in basic research on reaction mechanisms.	Microalgae: Developing tubular reactors. Have made progress with pond cultures. Constructing an information network that will encompass the entire EC. Breeding/photosynthesis mechanism: Conducting basic research.	Not active in CO_2 immobilization work due to stress on nuclear power. Catalysts: Developing catalysts for CO, CO_2/H_2 reactions.		Second generation CFCs: Under development. Third generation CFCs: CFC manufacturers are showing interest.

(Continued)

	Rarefied Combustion Denitration Catalyst Technology	Biological CO_2 Immobilization	Chemical CO_2 Immobilization	CO_2 Storage/Disposal (Oceans/Underground)	Alternative Substances to CFCs
United Kingdom		Breeding/photosynthesis mechanism: Conducting basic research.	Film isolation: Setting up a development program for CO_2/H_2 isolation film. Not showing any activity in area of recovering CO_2 as a useful substance.	Ocean disposal: Planning to throw CO_2 into the Atlantic Ocean on a test basis as part of coal research.	Second generation CFCs: Under development.
Others	Italy: Carrying out basic research at the EC Environmental Research Institute. Belgium: Kasorikuruben (phonetic) University is engaged in basic research.	Australia: 10,000 hectares of pond culture. Canada: Researching a continuous reactor for algae. Canada-Switzerland: Conducting basic research on the photosynthesis mechanism. India, Taiwan, Thailand, Mexico and Singapore are also working with pond cultures.	Canada: Isolation of CO_2 gas using a liquid film. Netherlands: Full-scale development of technology for isolating CO_2 using liquid and polymer films. Austria: Promoting projects based on environmental harmony energy strategies.	Netherlands: Studying a method for dissolving it in underground water reservoirs. Norway: Proposing a system of introducing CO_2 into relatively shallow waters of 500-1000m and allowing it to flow into the deeper waters of the ocean. Proposing tests in the Atlantic Ocean.	Second generation CFCs are being developed in a few places.

52a. (*) There is reason to believe the U.S. is carrying out research on disposing of compressed CO_2 in the oceans, dried up gas wells and on storing it as solid carbon.

(Supplement) R&D Undertakings in the U.S. Related to Photovoltaic Power Generation.

The U.S. Department of Energy (DOE) has embarked on a long-term program called SOLAR 2000 aimed at pooling the assets of the national government, private industry and investors to bring about the early realization of full-scale commercialization of photovoltaic power generation. This is a three-pronged program comprising the following three (3) elements:

[1] Development of technology to enhance the efficiency and lower the costs of solar batteries, and to evaluate the performance and reliability of photovoltaic power generation systems (PV Systems);

[2] Creation of a favorable environment for the introduction of a PV system market; and

[3] Development projects designed to lighten the risks involved with the commercialization of PV systems from the standpoints of technology, construction/operation, regulation and financing.

Mid- and Long-term Goals of Photovoltaic Power Generation Program (SOLAR 2000)

	Current Status (as of 1991)	Mid-term Goals (1995-2000)	Long-term Goals (2010-2030)
Module efficiency	5-15	10-20	15-25
Power generation costs ($/kWh) (1990 prices)	25-50	12-20	5-6
Useful life (years)	10-15	20	30
Total capacity (MW)	<50	200-1,000	10,000-50,000

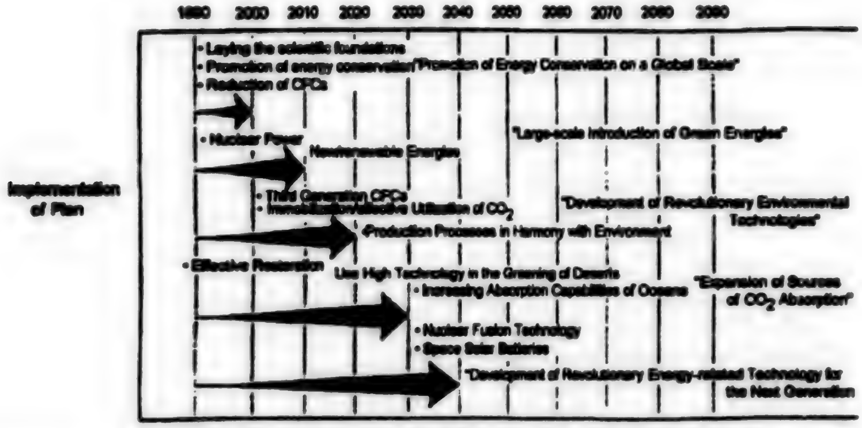
(Research by NEDO)

(Remarks) Sources of Items Cited in Reference 3.

- Energy Policies of IEA Countries 1991 Review (OECD/IEA)
- Overseas Information on New Energy (NEDO)
- Overview of Energy Situations and New Energy R&D by Country (NEDO)
- Current State of Cooperation and Future Direction of New Energy (United States, United Kingdom, Germany, France and Canada) (NEDO)
- Handbook of Energy Alternatives to Petroleum 1992 Edition (Published by the Agency of Natural Resources and Energy)
- FY1992 Science and Technology White Paper (Published by Science and Technology Agency)

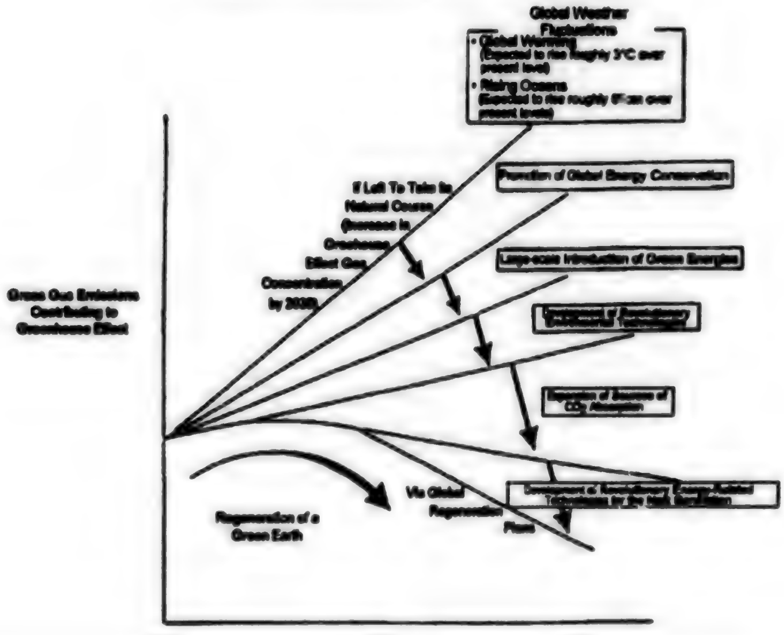
(Reference 4) Overview of the Global Regeneration Plan

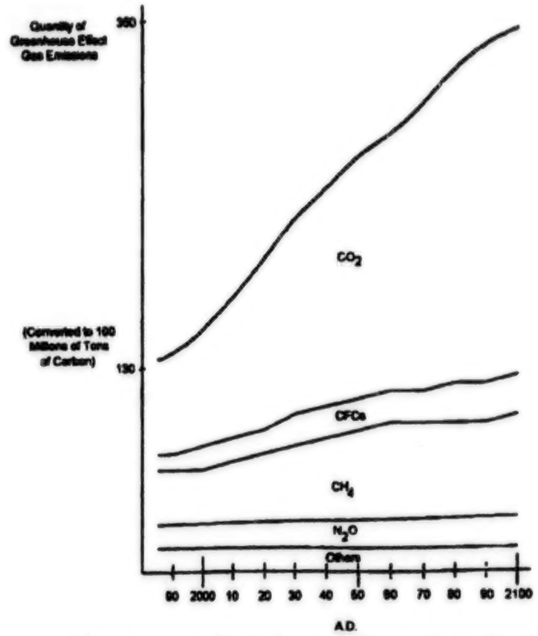
Overview of Global Regeneration Plan (1)



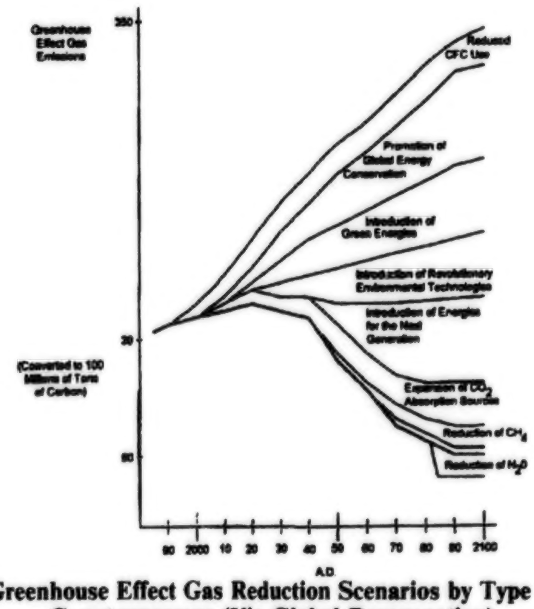
Graph shows the periods when the major effects of the plan should manifest themselves.

Overview of Global Regeneration Plan (2)





Expected Increases in Emissions of Gases Contributing Toward the Greenhouse Effect (If left to take natural course)



Greenhouse Effect Gas Reduction Scenarios by Type of Countermeasure (Via Global Regeneration)

International Communiques Regarding Global Regeneration Plans

1. Principle 9 "Science and Technology" from the Rio de Janiero Communique of June, 1992

Nations, in line with the exchange of scientific and technological knowhow, must cooperate to reinforce the enhancement of capabilities for sustainable development by means of increasing the development, application, dissemination and transfer of technologies, to include new and revolutionary technologies.

2. Agenda 21 (June, 1992)

Chapter 9 "Preservation of the Atmosphere (Global Warming, Acid Rain and Protection of the Ozone Layer)"

- Promote research of the mutual relationship between atmospheric changes and societies/economies;
- Development and promotion of low-pollution transportation systems;
- Development, improvement and application of environmental impact evaluation technologies;
- Strengthening of development capabilities aimed at creating manufacturing processes that are safe, easy on the environment and make efficient use of energy;
- Research on the impact of increased ultraviolet rays, and formulation of countermeasures based on that research; and
- Development of alternatives for ozone-depleting substances like CFCs.

Chapter 10 "Forests"

- Strengthening of R&D activities related to the application of improved genes and biotechnology toward the enhancement of productivity and environmental stress endurance.

Chapter 12 "Prevention of Droughts and Desertification"

- Promotion of the development of technologies for maintaining and acquiring water designed to prevent droughts and desertification;
- Development, experimentation and introduction of drought-resistant, high productivity plants.

Chapter 17 "Marine Environments and Biological Resources"

- Coordination of organized observations of key investigative elements in the management of the oceans;
- Strengthening of research activities aimed at reducing, controlling and preventing the degeneration of marine environments.

Chapter 18 "Fresh Water Resources (Rivers)"

- Application of new technologies aimed at minimizing pollution;
- Promotion of a comprehensive approach that integrates technological, socioeconomic, environmental and health problems;
- Promotion of recycling and waste disposal methods that do not bring about the degeneration of the environment.

Chapter 19 "Sound Management of Toxic Chemical Substances from an Environmental Standpoint"

- Development of capabilities for dealing with accidents;
- Strengthening of R&D on safe alternative substances;
- Promotion of technologies for minimizing the discharge of toxic chemical substances in all countries.

Chapter 20 "Toxic Wastes"

- Preparation of a comprehensive research program related to toxic wastes;
- Increased support for R&D of green technologies that make use of biotechnology.

Chapter 21 "Sound Management of Ordinary Waste Materials from an Environmental Standpoint"

- Strengthening of research into environmentally-safe technologies beginning with those that employ means of minimizing waste;
- Promotion of research activities and information related to the sound reutilization and recycling of waste materials from an environmental standpoint.

3. Economic Communique from the Munich Summit of June, 1992

Promotion of the development and dissemination of energy- and environment-related technologies, to include demands for revolutionary technological programs.

4. Economic Communique from the London Summit of July, 1991

Promotion of the development and dissemination of energy- and environment-related technologies.

5. Economic Communique from the Houston Summit of July, 1990

Recognize the need for joint efforts at development within the next several leap years of environmentally-safe technologies and methods for complementing energy conservation and other means of reducing the emissions of CO_2 and other greenhouse effect gases.

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